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# PRACTICE NETWORK MAPPING: DEVELOPING INTERDISCIPLINARY METHODOLOGIES TO EXPLORE LOW-CARBON COMMUTING

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**Practice Network Mapping: developing interdisciplinary methodologies to explore low-carbon commuting**

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## ABSTRACT:

The notion that energy is used as part of everyday practices has opened up new directions for research seeking to understand and generate low-carbon practices. To date, however, practice theory has had a limited impact on conventional forms of energy modelling and, as a result, on energy policy. This paper explores the challenges of attempting to 'model' social practices, drawing on techniques from practice network analysis to map the links between both elements and practices. To do this, it explores commuting as an example of a complex sociotechnical system of particular interest because of the expected future increase in vehicle electrification and the tendency for commuting to occur during times of peak energy demand. The paper reports on new empirical survey data in which participants sought to 'map' their commuting practices and their connections with other practices. We describe the methodology used to generate practice network maps of commuting. We argue that there are several benefits of this approach, including: i) it helps differentiate between core and peripheral elements of practices; ii) it helps identify clusters or ecologies of practice that are tightly interconnected and may therefore be difficult to intervene in; and iii) it focuses attention on connections between practices, encouraging energy modellers to broaden their understanding of the 'contexts' of energy demand. The paper concludes by reflecting on the value of this approach for both interdisciplinary energy research and for intervening to try and generate low-carbon practices.

**Keywords:** Social practice theory; low-carbon community; interdisciplinary energy research; practice network mapping.

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## 1. INTRODUCTION

Decarbonising different forms of mobility will be a critical and extremely challenging part of any attempt to reconfigure everyday practices for a low-carbon world (Hickman and Banister 2007). Despite many years of efforts to reduce transport-related CO2 emissions (Schwanen et al 2011), they remain very high and stubbornly resistant to change. The International Energy Agency (2013), for example, states that transport-related CO2 emissions account for 22% of all global CO2 emissions (IEA, 2013, p71). Worse, long-term trends in developed-world transport patterns show increases in levels of demand for mobility since the 1970s. The UK, for example, has seen a 49% increase in average distance travelled per person since the 1970s, with an increasing proportion of this travel being made in cars (Department for Transport 2016). It is clear, therefore, that attempts to de-carbonise transport will demand significant change in both the technological and social parts of existing mobility systems (Marsden et al 2014). Such attempts will likely require new technologies and infrastructures, new institutions and rules, new economic patterns and flows, as well as new forms of transport behaviour. Achieving all of this will thus demand new interdisciplinary approaches to understanding these dimensions of mobility systems and their multiple inter-relations (Schwanen et al 2011).

As part of this challenge, recent years have seen the growing application of theories of social practice to mobility (e.g. Watson 2013; Spurling and McMeekin 2015; Cass and Faulconbridge 2016). Among other things, theories of practice emphasise the multi-dimensional and inter-linked nature of mobility practices. In so doing, they highlight the limitations of approaches to transport policy that hold technology and behaviour distinct or that emphasise individual responsibility and choice (e.g. Chatterton et al 2015). Nonetheless, despite their growing application theories of social practice have, to date, had limited impact on transport policy and decision-making which remains predominantly focussed on shifting the vehicle fleet towards cleaner fuels and nudging individuals to make more sustainable choices (e.g. Marsden et al 2014). Further, and as Schwanen et al (2011) note, transport research itself is dominated by particular and partial modelling approaches and methodologies that maintain and amplify a focus on changes in the built environment, or the cost and fuel efficiency of particular types of vehicle, yet which struggle to grasp the role of social norms and values, or of wider institutions and stakeholders, in shaping how people travel (Schwanen et al 2011, p997).

This paper seeks to make progress in this area by introducing a new interdisciplinary methodology that seeks to 'map' social practices using social network analysis techniques. To do this, we apply the method to new exploratory empirical data about commuting practices. Crucially, however, the aim of the paper is not to generate new empirical insights into the social practices of commuting (this has already been done elsewhere e.g. Cass and Faulconbridge 2016). Rather, we aim to demonstrate the new methodological approach and explore its value in helping to inform and overcome some of the challenges currently being faced in this area.

The next section provides a brief review of the literature on decarbonising mobility systems, with a particular focus on how social practice theory has been applied in this area. Section 3 then describes the conceptual basis for and development of the interdisciplinary methodology we call 'Practice Network Mapping'. Section 4 demonstrates an experimental application of practice network mapping to new empirical data on commuting practices drawn from 62 survey responses. Section 5 discusses the benefits, limitations, and practical and research implications of the approach before outlining a number of ways in which it might be further developed. Finally, Section 6 concludes the paper by calling for new and more diverse modes and practices of interdisciplinary collaboration.

## 2. TOWARDS LOW-CARBON MOBILITY PRACTICES

In their review of research on climate change mitigation in transport, Schwanen et al (2011) argue that research has tended to address one, or sometimes several, of five core 'elements' of the transport system. First, the dominant focus of research in this area has been on *technology*. Here, emphasis is placed on vehicles powered by alternative, lower-emission fuels such as biofuels, hydrogen or electricity, as well as on the potential contribution of improved fuel efficiency to reducing CO2 emissions. A second core research focus explores different *economic instruments* that might be used to accelerate the diffusion of these cleaner and lower-emission vehicles, such as the role of fuel prices or carbon taxes. Third, research has examined the provision of new forms of *infrastructure* - such as cycle paths, public transport, high speed trains etc., - to enable greater uptake of low-emission forms of travel. Some of this work has also explored reducing the need for travel through interventions in land use planning (e.g. generating more walkable or cycle-able towns and cities) or by developing Information and Communication Technologies (ICTs) such as video-conferencing. A fourth core element that has been addressed, relates to encouraging forms of *behaviour change,* such as choosing more sustainable transport modes or forms of 'eco-driving'. Here, research has tended to concentrate on how lower-carbon transport behaviours might be brought about by changing people's attitudes, values and choices. Fifth, and finally, research on *institutions* has explored how transport policies are developed and implemented in different ways in different places, and how forms of policy 'lock-in' might be overcome.

Despite the diversity of these different research foci, Schwanen et al (2011) conclude that stronger emphasis is placed on decarbonisation through technology, economic instruments and infrastructure, with forms of institutional and behavioural change receiving less attention. Focusing on behaviour change specifically, Cass and Faulconbridge (2016) note that whilst early research conceived of travel as a 'utility maximizing behaviour' and thus adopted broadly rational choice models to understand how intervention might occur, more recent research has adopted a range of different social psychological models to explore various influences on people's choices, such as beliefs, norms, values, attitudes, habits and a range of 'situational factors'. More recently still, there has been a rise in 'nudge' based approaches (Thaler and Sunstein 2008) that seek to influence people's travel decisions

through changes to the wider 'choice architecture' (e.g. Jones et al 2013, chapter 4). These approaches all focus on individual choice and the idea that "carbon reduction can be achieved with minimal interference to the range of choices available to people and without upsetting current practices of mobility" (Marsden et al 2014, p74).

The use of choice-based approaches as a means of mitigating climate change has been a core focus of critique within theories of social practice (Shove 2010). To be clear, theories of social practice do not wholly deny a role for choice, or suggest that individuals' choices cannot be influenced in a range of important ways. Rather, they argue that a focus on individuals' choices will have limited impact so long as it fails also to address the wider social processes and systems which give rise to, maintain and extend social practices of, and related to, unsustainable travel (Marsden et al 2014, p73).

Accordingly, in trying to shed light on these wider social processes and systems, recent applications of practice theories to travel have deepened understanding in various ways. One key contribution has been to reveal the complex and multi-dimensional nature of travel practices as configured out of multiple inter-relating elements. Although there is no consensus on exactly what types of elements make up practices (Gram-Hanssen, 2011) there is general agreement that the organisation and performance of transport practices involves the integration of material elements (e.g. vehicles, road networks, petrol stations etc.,) with forms of social meaning (e.g. for speed, convenience, flexibility etc.,), and with a range of personal competences or skills (e.g. the ability to drive a car, to cycle in traffic, or to manage one's time etc.). In drawing these wide-ranging elements together, theories of social practice thus immediately recognise that change in travel practices is something that has to occur on a societal rather than individual scale, as well as along multiple inter-related dimensions.

By highlighting the complex configurations of travel practices, a second core contribution of practice theory has been to help reveal the specificity of different modes and types of journey. For example, as well as highlighting the clear differences in the elemental configurations of driving and cycling, it also highlights that there are multiple variants of each of these distinct practices. Leisure cycling, for example, will likely involve different elements from commuter-cycling. Further still, there will be further sub-divisions of leisure cycling between, say, mountain biking and road racing. Cass and Faulconbridge (2016) note, therefore, that a key contribution of practice theory to transport is the recognition that different "modes [of transport] only become meaningful when they are tied to and allow the completion of activities" (2016, p4). Thus, for example, cycle-commuting may have more in common with car-commuting or bus-commuting than it might with cycle-shopping. By helping to zoom in on specific travel practice in this way, practice theory thus militates against generic or one-size-fits-all approaches to policy which assume that interventions will have equivalent impacts across different types of journey.

A third core contribution practice theory has made to understanding mobility is the recognition "that there is little value in thinking about demand for mobility in its own right; rather, mobility is a demand derived from the interconnections of practices, including

working, shopping and leisure" (Spurling and McMeekin 2015, p92). In short, and extending the argument made by Cass and Faulconbridge (2016) above, practice theorists note that it is the distribution of practices across space and time that gives rise to the need to travel in the first place. Thus, if domestic and work practices were spatially located in the same building, there would be no need to commute. Similarly, if people engaged in fewer practices in the course of their daily lives, there may be less need to travel so far or so fast. Thus, interventions aiming to decarbonise transport should zoom out to look beyond specific modes of transport or types of journey, and to think more about the wider systems of practice that transport practices are part of and uphold (Watson 2012; 2013)

Drawing on these insights, Spurling and McMeekin (2015) identify three distinct ways in which interventions have been, or could be, made into mobility practices. '*Recrafting practices*' involves changing the elements of existing mobility practices in order to reduce their resource intensity or associated CO2 emissions. Although not commonly framed as an intervention into the elements of practices, many existing transport policies adopt this approach such as when, for example, they seek to introduce new, low-emission vehicles, help drivers develop new skills to 'eco-drive' their cars, or when forms of social marketing or information campaigns are used to promote cycling or public transport. A key insight from practice theory is that this kind of intervention is more likely to succeed if 'multidimensional interventions' (Spurling and McMeekin 2015, p84) that tackle multiple different elements simultaneously are developed. Rather than seeking to reduce the carbon intensity of existing practices, 's*ubstituting practices*' focuses instead on the wholesale replacement (or substitution) of high-carbon mobility practices with lower-carbon ones, for example through forms of modal shift wherein cars are replaced with trains or bikes. This form of intervention involves trying to alter the 'balance of competition' between competing practices and thus suggests that interventions should not merely promote new lower-carbon practices, but should simultaneously demote other, higher-carbon modes of travel. Perhaps the key novelty of this insight is thus the need to intervene in two practices at the same time. *Changing how practices interlock* is a still less common form of intervention that directly addresses the observation that demand for mobility is produced by wider systems of practices and how they are distributed across time and space. This is a far more radical type of intervention that seeks to challenge and re-specify the 'need' for mobility by, for example, generating new 'time space matrices' (Cass and Faulconbridge 2016) that enable rather than constrain low-carbon travel.

Whilst practice theory has thus added much to understandings of mobility and of how it might be intervened in, to date it has had very little impact on policy decisions and has not yet been used to directly inform many practical interventions (Shove 2010; 2012). One potential way around this is the generation of new methodologies that are based on and may promote the use of practice theories to inform interventions. In their review, Schwanen et al (2011) note that transport research on climate change mitigation is dominated by two distinct types of methodology: i) regression or discrete choice modelling to infer how much impact specific interventions (e.g. land use or behavioural change) might have in reducing CO2 emissions; and ii) scenario approaches which use a variety of modelling techniques to forecast future trends based on "past trends and assumptions about technology

development and uptake, price levels and sensitivities, behaviour change, population growth etc." (Schwanen et al 2011, p995). In the best case, they note that these approaches struggle to capture the full complexity of mobility systems and practices – particularly in relation to changes in social norms, values and institutions. In the worst case, however, they note that these approaches "have become inextricably linked with many transport researchers' practical understandings of the phenomena they study" (Schwanen et al 2011, p995) leading to forms of 'disciplinary lock-in' which prevent other ways of defining problems and generating solutions. What is needed, therefore, are new conceptual and methodological approaches that actively draw attention to the specific elemental composition of different practices and to how different practices relate and interconnect with one another across space and time in larger systems of practice. In the rest of this paper we introduce one such approach – practice network mapping – and explore how it might be applied to new empirical data on commuting practices.

## 3. METHODOLOGY: DEVELOPING PRACTICE NETWORK MAPPING

The challenge of developing new and interdisciplinary approaches and methodologies is neither new, nor specific to research on transport. Indeed, it is a common challenge across the broad domain of research on attempts to tackle climate change or generate sustainable energy transitions (e.g. Barry et al 2008; Mallaband et al 2017; Pellegrino and Musy 2017; Smith et al 2017; Winskel 2018). As such, developing interdisciplinary approaches was at the core of the UK Engineering and Physical Sciences Research Council funded 'Realising Transition Pathways' (RTP) research project. In a previous round of funding for the same consortium, Hargreaves and Burgess (2010) identified that despite a general enthusiasm for interdisciplinary collaboration, this often collapsed when faced with the challenge of combining often small-scale, detailed qualitative insights about energy use with large-scale, quantitative energy system models. To address this, the RTP project adopted an actively experimental approach that recognised no single 'best practice' way of doing interdisciplinarity (Longhurst and Chilvers 2012), but sought instead to develop and trial multiple different means and modes of interdisciplinary research around energy system models. In this paper, we focus on one particular interdisciplinary experiment that, rather than trying to integrate qualitative insights into pre-existing energy models, sought instead to devise new ways of constructing energy system models based in theories of social practice. Social practice theory was chosen precisely because it was recognised as at the cutting edge of energy social science research, but has so far had limited impact on modelling and, in part by extension, on policy and decision-making (Shove 2010).

Whilst there is no single, agreed version of practice theory (Schatzki 2001), most definitions and depictions of practices recognise them as comprised of "several elements , interconnected to one another" (Reckwitz 2002, p249) and emphasise that their form and existence depends precisely on the "specific interconnectedness of these elements, and…cannot be reduced to any one of these single elements" (Reckwitz 2002, p250). As Figure 1 shows, Shove et al (2012) depict practices as made up of three different types of

elements – meanings, materials and competences – with the making and breaking of links between these elements serving to both stabilise and animate practices.

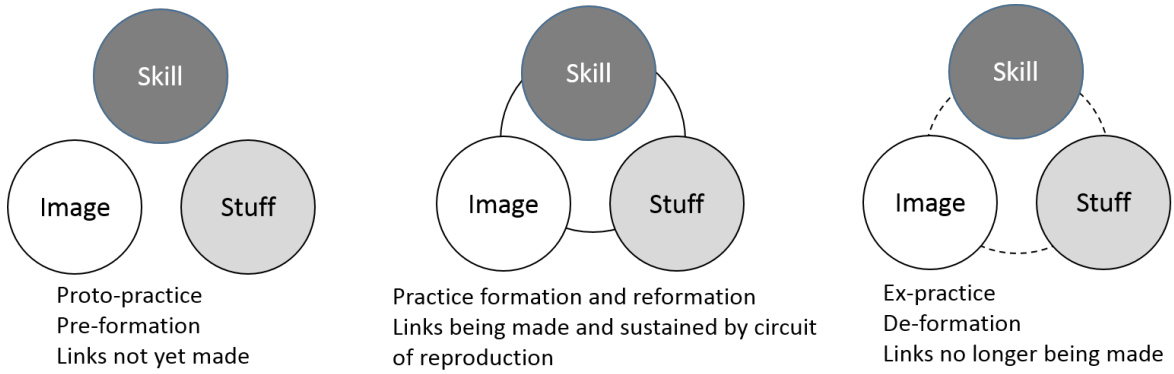



**Figure 1: Proto-practices, practices and ex-practices** (Source: reproduced from Shove et al 2012, p25)

Building on Shove et al's (2012) tripartite model, Kuijer (2014) notes that any individual performance of a practice will likely involve multiple meanings, materials and competences, such that each individual element category consists of a "constellation of groupings of elements" (Kuijer 2014, p52). This is depicted in Figure 2 which, crucially, demonstrates that not every performance of even the same practice will involve precisely the same configuration of elements. Thus, whilst a single practice-as-entity (e.g. cycling) will be made up of very large numbers of different elements, each individual, temporally and spatially specific performance of cycling (e.g. commuter-cycling, mountain biking, road racing etc.,) may make use of only some of these elements and not others. Thus, whilst some elements may be very strongly linked together and consistent to all performances (e.g. a bicycle of some sort, the ability to cycle, the meaning of speed – represented by larger circles and thicker links), other links will be less consistent such that the precise configuration of elements involved in any specific performance will differ.

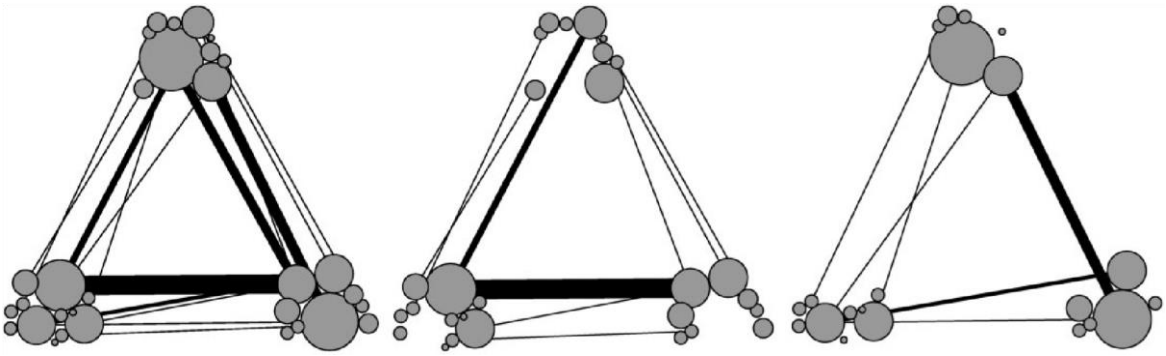


**Figure 2: Practices as comprised of constellations of elements** (Source: Higginson et al 2015, p954; Based on Kuijer, 2014)
**Notes:** Figure depicts a practice-as-entity (left) and two different performances thereof (centre and right)

As both Figures 1 and 2 show, depictions of practices tend to take the form of networks, in which, to use the terminology of social network analysis, the elements of practice represent the 'nodes' of networks and the connections between these elements the so-called 'edges' or relations between them (Scott and Carrington 2011). This simple observation, that practices resemble networks, inspired us to further explore how practices might be understood or represented as networks, with each distinct practice-as-entity having its own distinct geometry formed through the constellations of groupings of elements and connections between them that make it up, and each practice-as-performance representing a spatially and temporally distinct variant thereof. Crucially, if data could be collected that captured the distinct elements and relations involved in a particular performance of a practice, then the techniques of social network analysis, and particularly of network visualisation, could be used to generate graphs that serve to 'map' the distinct geometries of different practices.

Our initial attempt to collect such data involved asking participants to list the different kinds of elements involved in their laundry practices, but did not ask them to reflect on or give any indication of the connections between these elements (Higginson et al 2015). Thus, to further develop the technique, we administered a pilot survey to 62 participants (43 students at the University of East Anglia, and 19 employees from Loughborough University). The survey tool simply asked these participants to 'draw' their most recent commute, listing the different elements (meanings, materials, competences) it was made up of and drawing connections between the elements they saw as connected. Figure 3 displays an example of the sorts of hand-drawn map this produced, while Table 1 summarises the different types of commuting performance included in the sample.

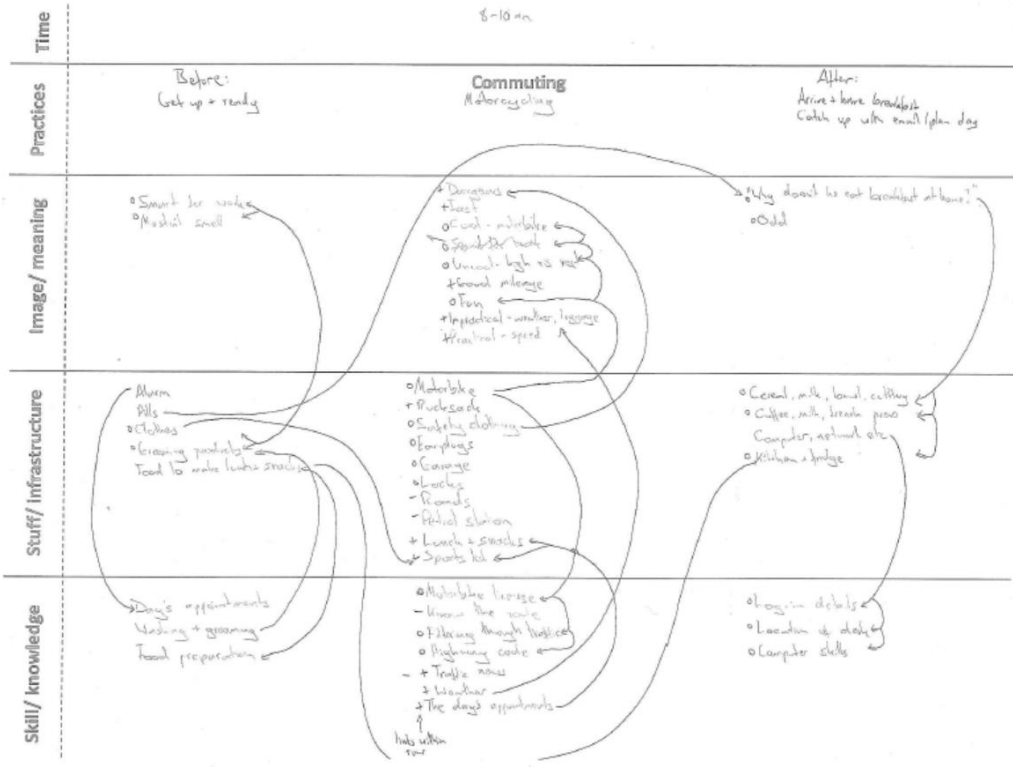


**Figure 3: Example of a completed survey showing a participants' hand-drawn map of their commuting practice**

| Commuting variant | Number of surveys |
|---|---|
| Car-commuting | 16 |
| Walk-commuting | 20 |
| Motorbike-commuting | 1 |
| Public Transport-commuting | 8 |
| Bicycle-commuting | 17 |
| **TOTAL** | **62** |

**Table 1: Summary of commuting variants included in full sample**

Each of these hand-drawn maps were then coded into an 'incident matrix' in Excel. For each participant, this involved noting the type of commuting being performed, listing all the elements (nodes) included and what type (meaning, material, skill) they were, and recording all of the connections (edges) drawn between elements. For each connection a note was made of both the 'source' and 'target' element but, as the survey did not ask participants to further describe the connections or the directionality of them, all were listed as 'undirected' connections. The extensive list of elements this produced was then rationalised so that different descriptions of the same element were given the same label (e.g. 'bike' and 'cycle' both became 'bicycle'). A Matlab script was then written to convert the survey incident matrix into a nodes table and an edges table. These were imported into the open source network visualisation and analysis tool Gephi to generate network graphs for each variant of commuting included in the data. 'Force atlas' layouts were chosen to arrange the elements in the graph as this helps ease the readability of the graph and, where possible, avoid overlapping connections between elements. Filters were also used to highlight different kinds of elements in different colours, and to size both nodes and edges according to their frequency.

These initial steps served to generate 'element network graphs' that display the configuration of elements of distinct commuting practices. Driven by the importance of recognizing commuting as part of wider systems of practice (Watson 2012; 2013) and therefore attending to the connections between practices as well as between their elements, we then re-coded the surveys again to generate 'practice network graphs' that explore links between different types of practices. There are many potential ways in which this could be approached, for example to emphasise spatial or temporal connections between practices. We have begun to explore some of these approaches elsewhere (McKenna et al 2020). Here, however, we noted that many of the elements of one practice are resources for or the products or outputs of another (Boons and Welch 2015). Accordingly, we re-coded the elements of commuting practices to identify the broader practice or system they appeared to come from. For example, where participants had listed 'books' as part of their commute this was re-coded as part of the practice of 'work'. Similarly, 'breakfast' was recoded as part of 'eating', or 'traffic lights' as part of 'road planning'. There were many subjective interpretations involved here and, as Boons and

Welch (2015) observe, there are ongoing disputes about how to classify or draw boundaries around practices. Our purpose here, however, was simply to experiment with practice network mapping as a new methodology, rather than to generate new empirical insights about commuting.

The next section presents and discusses several of the graphs that resulted from this analysis. It is important to remember that this empirical work was done in an experimental vein and with a small sample of participants. As such, the aim of the next section is to explore the value of this developing methodology in opening up new questions or intimating new kinds of insight.

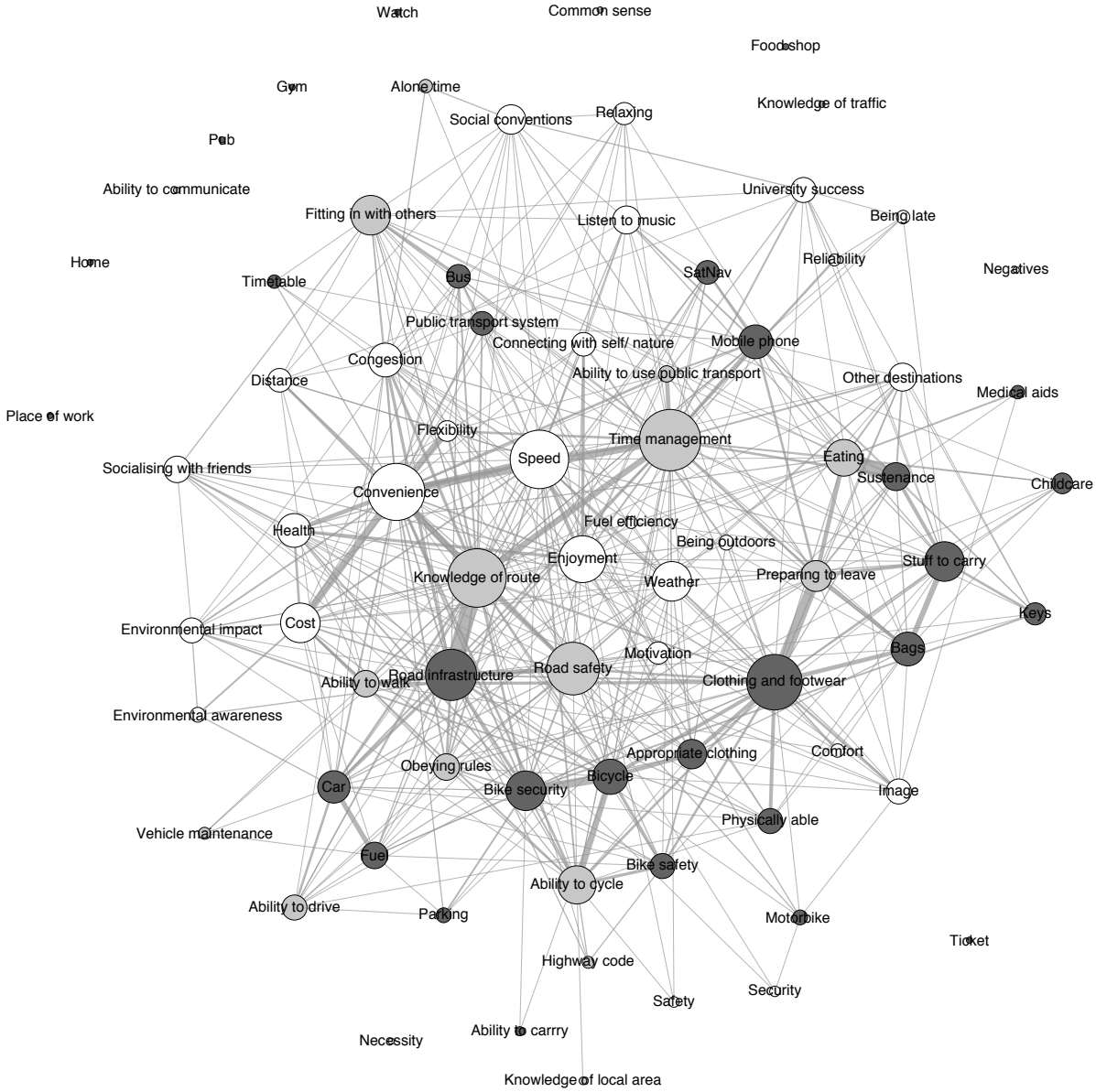
## 4. RESULTS

### 4.1 The elements of commuting

Figure 4 is an element network graph displaying all of the elements and connections across all 62 performances of commuting contained in our sample. As an image, or representation of commuting, some features are immediately apparent that prompt further discussion or inquiry into the nature of commuting as a social practice. Perhaps most immediately arresting is the sheer complexity of the graph with very large numbers of different kinds of elements that are, at times, very densely interconnected. This serves very quickly to illustrate the inseparability of different kinds of element in the course of a normal daily commute. For example, the graph shows how different technologies (e.g. 'car', 'bicycle', 'bus' etc.), social meanings (e.g. 'speed', 'convenience' etc.) skills and competences (e.g. 'knowledge of route', 'ability to cycle' etc.), as well as institutionalised rules and procedures (e.g. 'highway code' etc.) are all inextricably part of commuting performances.

Beyond this immediate complexity, however, it is also possible to discern some patterns within the elements and connections involved. There are, for instance, several closely connected clusters of elements associated with different variants of commuting. For example, the cluster of 'car', 'fuel' and 'ability to drive' (bottom-left of Figure 4), or 'bicycle', 'bike security', 'bike safety' and 'ability to cycle' (bottom-middle). The size and location of the elements also illustrates that some were more frequently mentioned and would thus appear to be more central or core elements to commuting, whilst others are more peripheral. For example, the strongly interconnected elements of 'speed', 'convenience', 'cost', 'time management', 'knowledge of route', 'road infrastructure' and 'road safety' appear to be core to all commuting variants included in the sample. The thickness of the connections also indicates how frequently two elements were understood to be linked together, perhaps suggesting that these connections might be harder to break or change. The figure as a whole is then surrounded by a number of unconnected 'orphan' nodes whose role within and relation to commuting is perhaps less clear, frequent or stable. A final observation is that several elements on the figure, particularly among these orphan nodes, are not clearly related to modes of travel (e.g. 'pub', 'gym', 'food shop', 'childcare') these point toward both the increasing frequency of 'trip chaining' as part of a commute

(Chatterton et al 2015) but also to the longer sequences of practices over the course of a whole day of which commuting is merely one part of.




## Figure 4: An element network graph for the full sample of 62 commuting performances

**Notes:** Elements are colour coded such that white = meanings; light grey = competences and dark grey = materials – the same colours are used for all element network graphs. The size of the nodes and the thickness of connections represents the frequency with which they were mentioned in surveys. The location of the node (central/peripheral) represents the number of connections participants drew between it and other nodes such that more connected nodes appear more central. These conventions are applied to all element network graphs.

Whilst Figure 4 thus enables some interesting observations about commuting-in-general, as Cass and Faulconbridge (2016) note, social practice theory highlights the importance of going beyond a focus on the generic commute, to distinguish between distinct commuting variants. To this end, Figures 5-8 present element network graphs that zoom in on car-

commuting, bicycle-commuting, walk-commuting and public transport-commuting (all variants of commuting contained within our sample where n=>5).

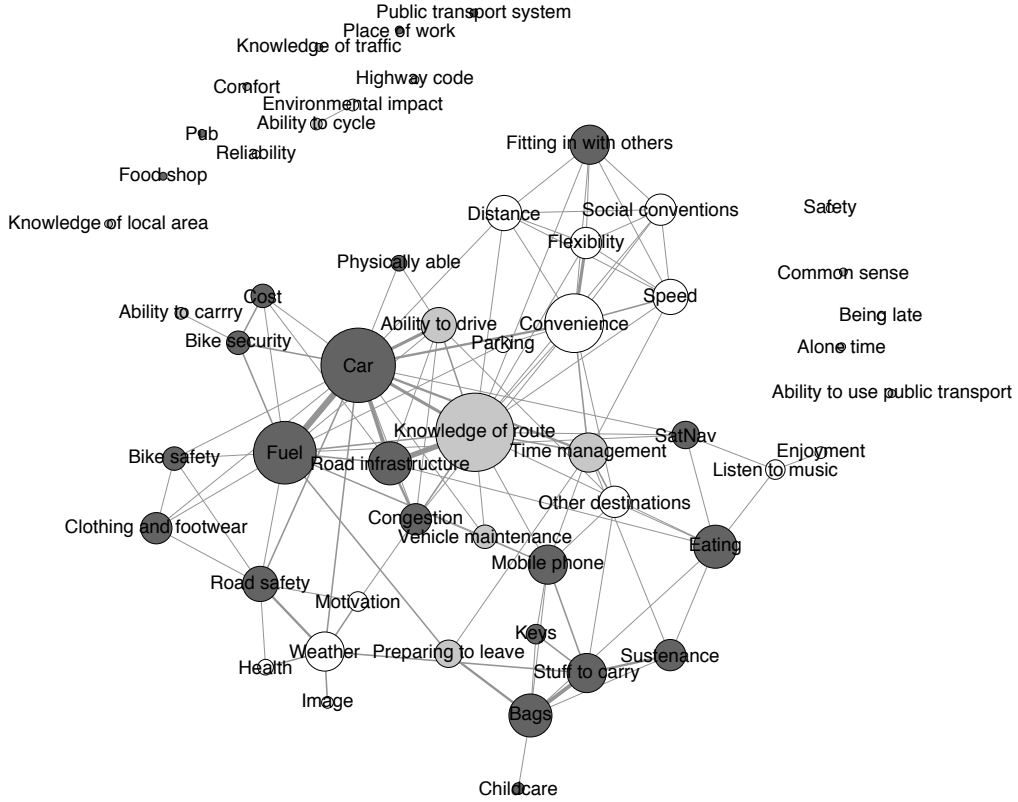



**Figure 5: Element network graph for car-commuting (n=16)**

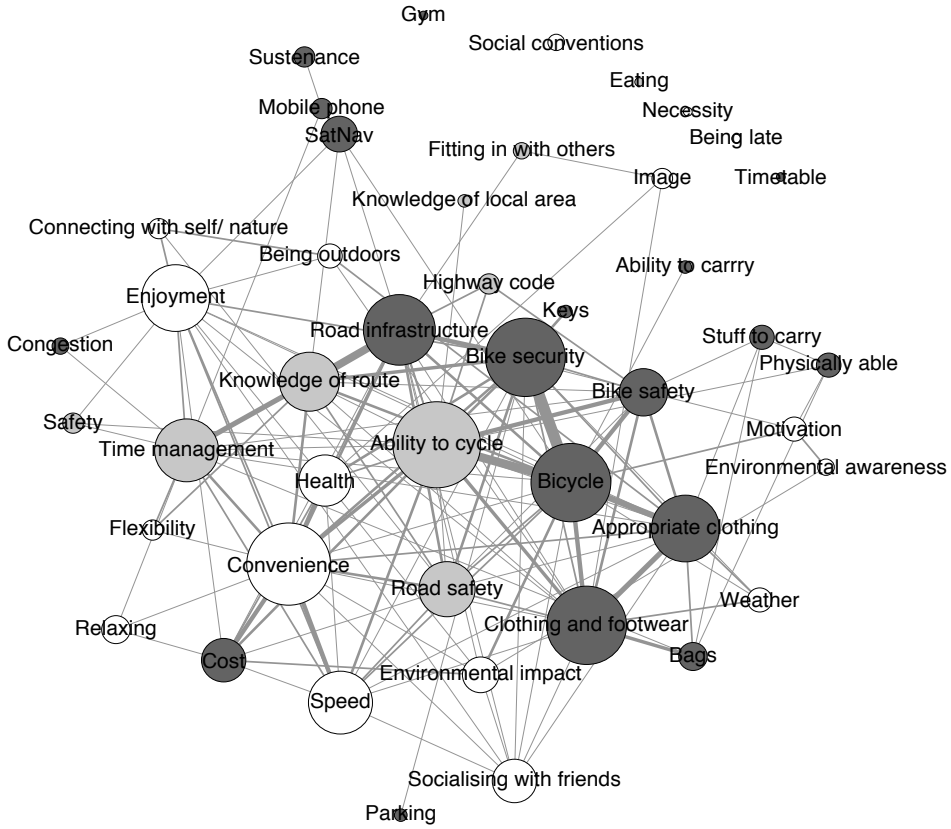



**Figure 6: Element network graph for bicycle-commuting (n=17)**

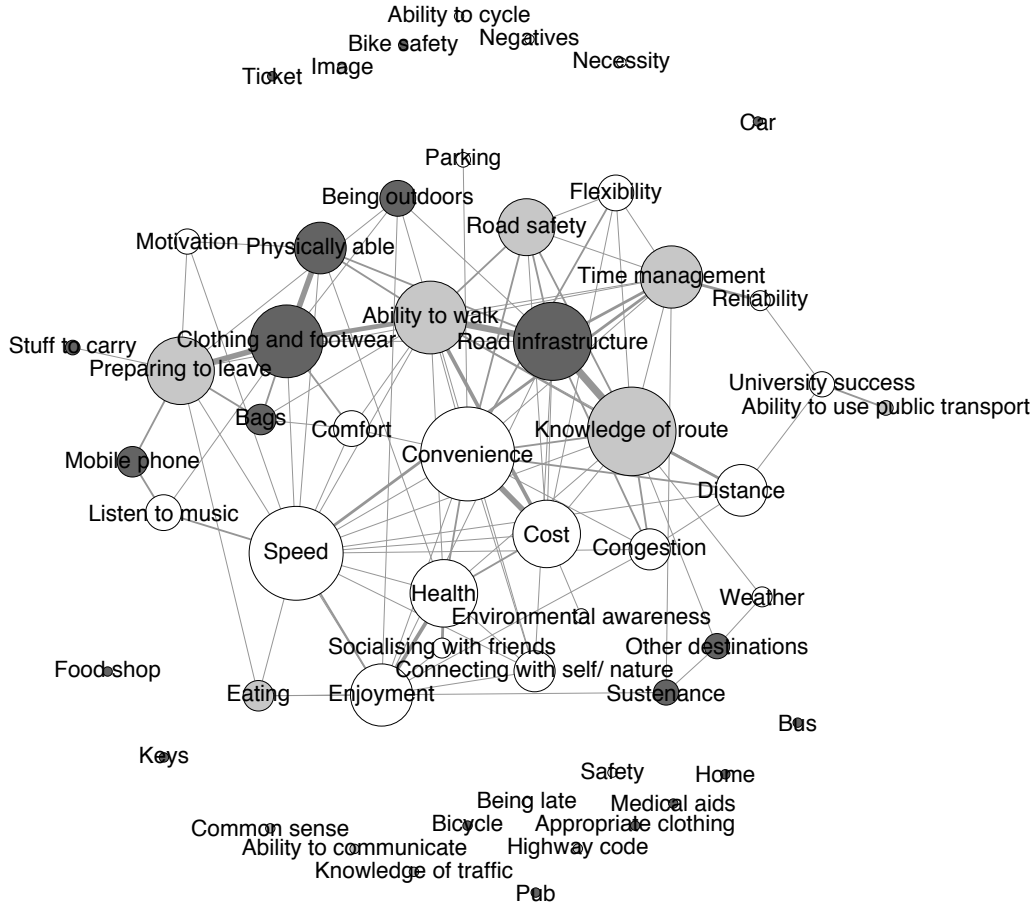


**Figure 7: Element network graph for walk-commuting (n=20)**

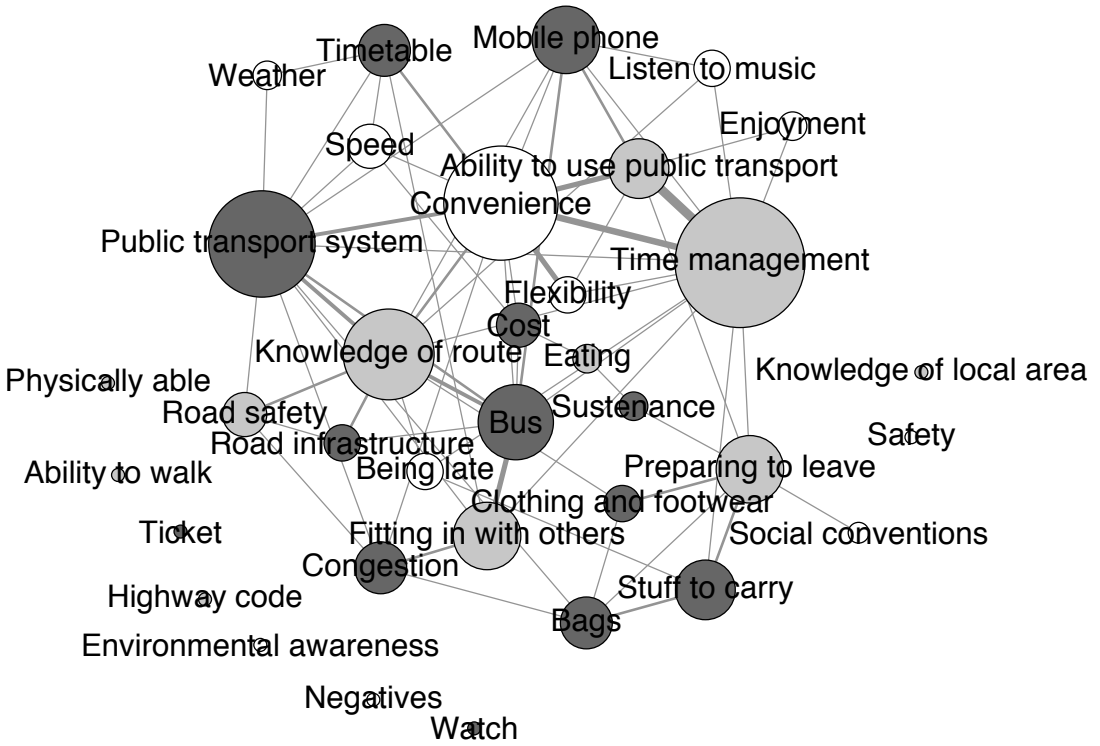



**Figure 8: Element network graph for public transport-commuting (n=8)**

Many of the features observed in Figure 4 are again apparent in Figures 5-8, but these more specific element network graphs also highlight a number of important differences between different types of commute. For example, whilst most elements appear in all types of commute (e.g. speed, convenience, congestion, clothing and footwear), these elements are more or less commonly noted (represented by the size of the node) and more or less interconnected to other elements (represented by the centrality of the node to each graph) in each different variant. As might be anticipated, for example, 'congestion' appears to be far less significant to bicycle-commuting (small and peripheral node to the left of Figure 6) than to car-commuting (larger, centrally located in Figure 5). Similarly, clothing and footwear seem to be much more important elements (larger, more central nodes) to bicycle- and walking-commutes (Figures 6 and 7) than to car- and public transport commuting (Figures 5 and 8).

There are also notable differences in the density of interconnections between elements in Figures 5 to 8. Specifically, the elements of car-commuting (Figure 5) appear to be much less densely interconnected than those of all other commuting variants (Figures 6, 7, & 8). Further analysis on the network density of these graphs would be required to establish this more objectively and further research would then be needed to explore why this might be the case. Nonetheless, developing an argument proposed by Cass and Faulconbridge, however, the relative simplicity of car-commuting may reflect "the wider dominance of the logics of driving in society and the complex ways in which systems of automobility structure all aspects of everyday life" (2016, p6). In short, precisely because much of everyday life is

based around the car, car-commuting may appear to be relatively simple, whilst other commuting variants may demand more, and more complexly-interconnected, elements.

Finally, Figures 5-8 also present a number of elements that are not clearly related to the specific commuting variant represented in the graph. For example, 'university success' appears as an element of walk-commuting (to right of Figure 7), 'gym' appears as a cycle-commuting (top of Figure 6) and both 'food shop' and 'pub' appear as elements of car-commuting (top-left of Figure 5). Perhaps tellingly, however, Figure 8 which depicts public transport-commuting appears to have fewer of these non-commuting related elements possibly reflecting the relative inflexibility of public-transport commuting compared with other variants. At the same time, and perhaps again reflecting the dominance of 'driving based logics' that have seen the car become a "'coping mechanism'…for managing the complex routines of everyday life" (Chatterton et al, 2015, p5), it is potentially significant that car-commuting appears to be interconnected to a greater variety of non-commuting related elements.

### 4.2 Commuting within systems of practices

In addition to zooming in on the elements of commuting and its variants, the practice network mapping technique can also be used to zoom out beyond single practices to explore the wider systems of practice of which they are part. As noted in Section 3, the elements of one practice are very often the outputs of or resources for other practice (Boons and Welch 2015). As such, although there are many ways in which this might be done, the second step of developing the practice network mapping methodology for this paper was to re-code the elements of commuting variants to reflect the broader practices or systems they appeared to come from. This process served to produce Figures 9-11 which display 'practice network graphs' for just three of the commuting variants contained in our sample: car-commuting (Figure 9); bicycle-commuting (Figure 10) and walk-commuting (Figure 11).

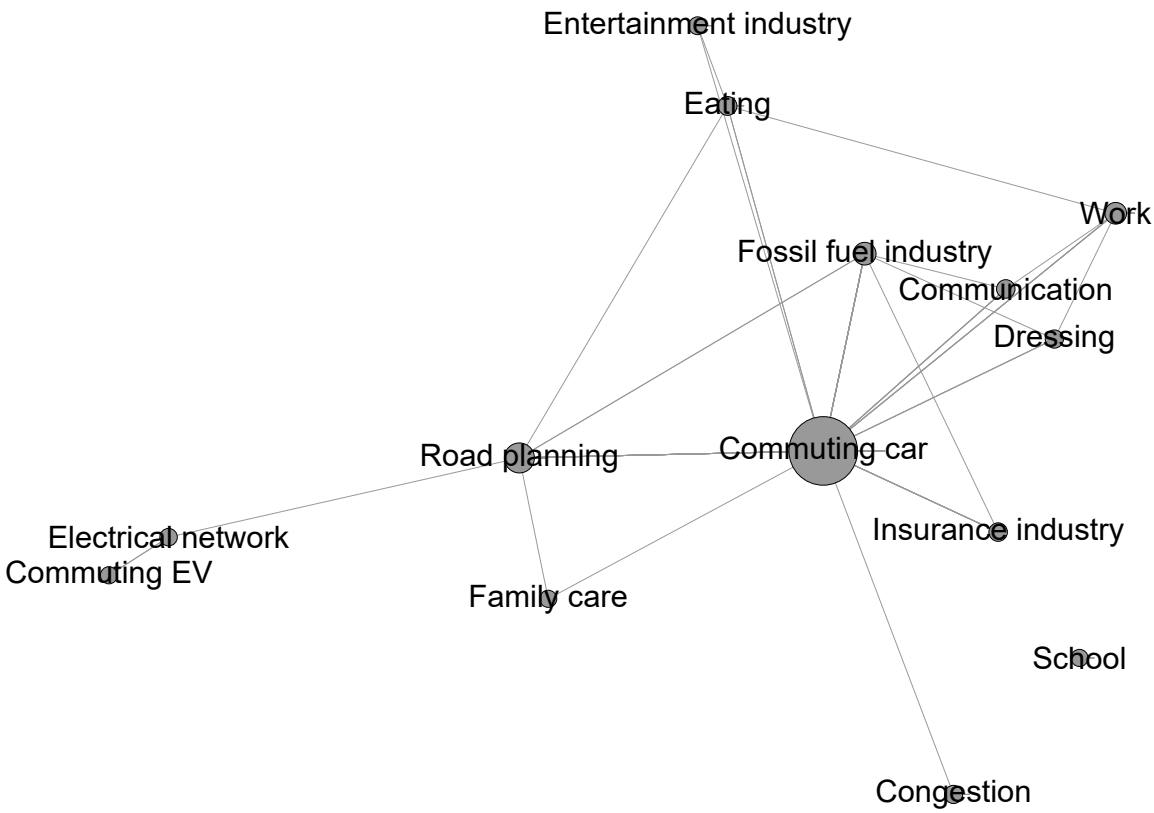



**Figure 9: Practice network graph for car-commuting (n=16)**

**Notes:** Each node represents a different practice. Size of the nodes and the thickness of connections represents the frequency with which they were mentioned in surveys. The location of the node (central/peripheral) represents the number of connections participants drew between it and other nodes such that more connected nodes appear more central.

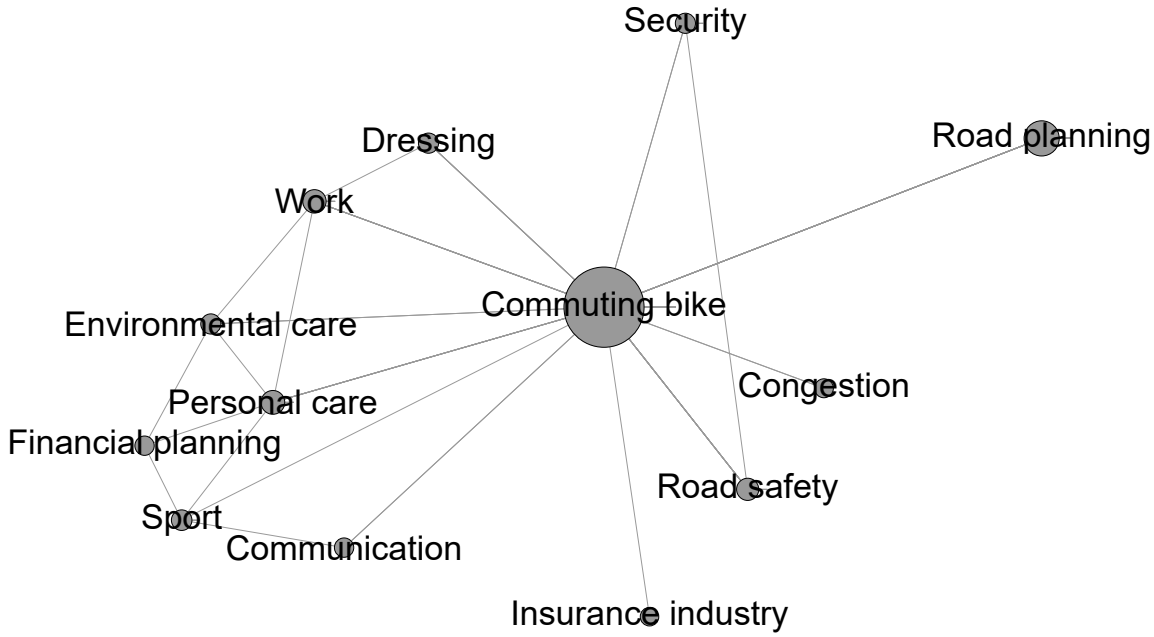



**Figure 10: Practice network graph for bicycle-commuting (n=17)**

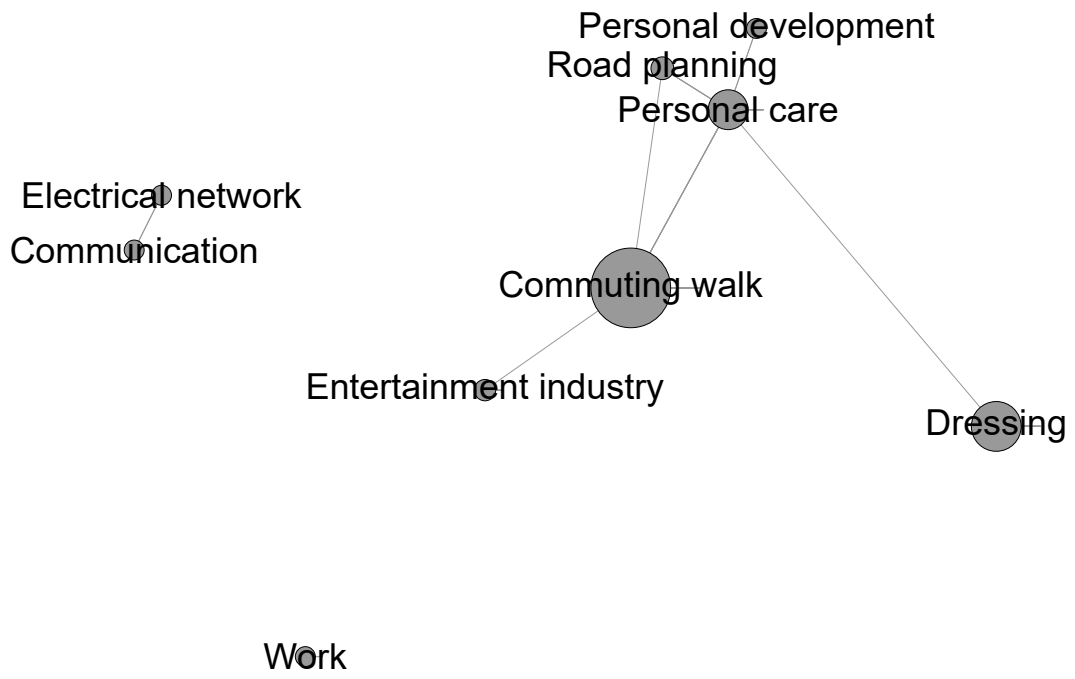



**Figure 11: Practice network graph for walk-commuting (n=20)**

Figures 9-11 show that there are many overlaps between the wider systems of practice in which these different commuting variants are situated. For example, all three of these commuting variants make use of roads and pavements and are thus part of a wider system of practice involving 'road planning'. Similarly, car- and bicycle-commuting are both connected to the 'insurance industry'. However, there are also some distinctive features of the graphs; for example, the 'fossil fuel industry' (derived from elements referring to 'petrol stations' or 'fuel') only appears in car-commuting (Figure 9), whereas 'road safety' and 'security' appear only in relation to bicycle commuting (Figure 10).

In addition to these shared or distinctive elements, Figures 9-11 also differ in the number of interconnections between practices that they display. The system of practices around car-commuting (Figure 9) is most densely interconnected, suggesting that car-commuting is not only connected into wider and more extensive systems of practice, but is also that this wider system of practice is closely interlinked with car commuting being a key practice within much of contemporary everyday life (Cass and Faulconbridge 2016). Bicycle-commuting (Figure 10) is also interconnected with a wide range of other practices although there is a lower density of interconnections with other practices in this network, whereas walk-commuting (Figure 11) displays a low density of interconnections perhaps suggesting that walking, as a mode of commuting, is relatively isolated from other practices.

The key point made by practice theorists and clearly visualised in these graphs is that any intervention designed to decarbonise transport needs to reflect not only on how to change the elements of existing transport practices, but also on how this is likely to impact on, and be impacted by, the much wider, even globally extensive systems of practice within which different variants of commuting are embedded.

## 5. DISCUSSION

The aim of this paper is not to generate new empirical insights into the social practices of commuting, but to demonstrate, develop and discuss the value of practice network mapping as a new, interdisciplinary methodology in helping to inform and overcome some of the challenges currently being faced in this area. This brief discussion will thus consider some of the benefits and limitations of practice network mapping, and highlight some potential policy and research implications.

As Section 4.1 showed, perhaps the core benefit of practice network mapping is that, through the creation of element network graphs, it can very quickly reveal not only the immense complexity of different practices, but also the overlap between the elements they are composed of, as well as the unique elements that distinguish practices from one another. In communicating this information through a visual representation of practices as networks of elements, practice network mapping also helps to pose previously unasked questions about the elemental configuration of practices, such as about the relationships and differences between 'core' and 'peripheral' elements. As well as sharpening the focus on elements, another benefit of practice network mapping is that it also opens up new questions about the "thinness and thickness and directness and circuitousness (Schatzki 2011, p71) of the relationships between them. For example, it may reveal elements that are strongly interconnected to one another, as well as those that appear less embedded within practices. The method thus helps to zoom in on specific parts of practices as a means of informing further, more detailed research into their structure and dynamics. Beyond single practices, Section 4.2 also demonstrated that practice network mapping can be easily adjusted to zoom out and focus on wider systems of practices. This helps to raise new questions about the relative embeddedness of different practices within wider everyday life or to other globally extensive systems. Finally, a potentially major benefit of practice network mapping is that it is relatively easily scalable. Where much research within social practice theory is based on in-depth, historical or ethnographic work (e.g. Cass and Faulconbridge 2016) and is thus often limited to small-n samples, practice network mapping can incorporate larger sample sizes which may help build connections with the more conventional quantitative and modelling approaches used in transport research (Schwanen et al 2011) and make practice theories more attractive to policy and decision-makers. In short, because practice network mapping is scalable and produces relatively easy-to-intepret visual outputs, it provides a helpful way to talk to policy makers about practices, and may also help to improve the underlying assumptions of existing modelling and policy approaches. (McKenna et al 2017)

With regards to informing policy and practical interventions in practices, the results presented in Section 4 both reinforce some existing insights and suggest some new ideas and sites for intervention. In demonstrating the distinctiveness of different variants of commuting, for example, Figures 5-8 strongly support Cass and Faulconbridge's (2016) argument that different types of commute will require different interventions. Going further, practice network mapping also reveals possible points of intervention into specific commuting variants. The element network graphs, for example, not only provide a list of the

meanings, materials or competences that might be intervened in, but, by displaying the interconnectedness of these elements they also guide would-be interveners to consider potential knock-on effects of any such intervention across the wider practice as a whole. Going further still, by helping to identify and raise questions about core or peripheral elements within practices and about the density of interconnections between elements, practice network mapping also implies that more peripheral elements may be easier to intervene in than others. Or, in contrast, that successfully intervening into 'core' elements may have dramatic impacts across whole practices (cf. Mylan 2015).

Moving beyond single practices, the practice network graphs presented in Figure 9-11 also demonstrate how commutes of different types are embedded into distinctive systems of practice spread across both space and time. This strongly supports the recognition that interventions into practices should be thought about in a much more systemic manner (Watson 2013). One practical implication of this is that interventions to decarbonise mobility may be more effective if they focus instead on non-mobility practices as a means of changing how practices interlock within wider systems (Spurling and McMeekin 2015). The value that practice network mapping adds to this is that it rapidly generates new insights into exactly which practices are interlocked with one another and may thus help in targeting such interventions or in thinking through their potential consequences.

Overall, therefore, we would argue that practice network mapping represents a valuable new methodology that can help generate new research insights, inform further research, and aid practical and policy decision-making. At the same time, we recognise that it has several important limitations. In particular, whilst on the one hand it serves to quickly identify and communicate the complexity of different practices, on the other hand it also lacks the depth, detail and nuance provided by more in-depth historical or ethnographic research into practices. While practice network mapping can therefore suggest important elements or connections within practices that might be the subject of further research, further research would be necessary to understand the qualitative nature of those elements and connections. A further limitation is that practice network mapping provides only a static snapshot of what are in fact dynamic and iteratively (re)produced practices. Whilst several practice network maps could be produced to track change through time, further in-depth research would again be required to understand the dynamics of practice and what animates their trajectories (see McKenna et al 2020 for some initial experiments in this area).

Despite these limitations practice network mapping has exciting potential and, given its currently experimental and exploratory state, there are many different ways in which it could be further developed. As simple suggestions, it could be used to explore the sequencing of practices throughout a particular time period (cf. McKenna et al 2020), or to explore differences and local variations in the configuration of practices across space. It could also be used to ascertain whether different groups of practitioners – e.g. categorised socio-demographically or by their experience within a particular practice – understand and perform practices in similar ways. The technique could also be developed to further examine the connections between elements or between practices such as to develop understanding

of what flows along them, what different types of connection there might be and whether or not they exhibit different levels of strength or intensity (Boons and Welch 2015). As well as these new lines of enquiry, different data collection approaches could also be used with the technique. Where we chose to use a survey-based approach, data could also be gathered in more in-depth and deliberative ways, such as through interviews or focus groups. This may help add depth to the insights generated by the technique and go further in linking or even integrating qualitative and quantitative methods.

## 6. CONCLUSION

This paper has introduced a new interdisciplinary methodology – practice network mapping – demonstrated how it can be applied to analyse new empirical data on commuting practices, and discussed its value and further development. Whilst the paper did not aim to generate new empirical insights about ways of decarbonising mobility, it has reinforced a number of key ideas emanating from theories of social practice, for example that different variants of commuting require different types of intervention, that intervening in the elements of commuting practices might be a valuable mode of intervention and, perhaps most crucially, that any attempt to generate a low-carbon society will demand systemic approaches that understand how specific practices – such as variants of commuting – are embedded within wider systems of practice. The approach has also opened up some new questions such as around the difference between core or peripheral elements, about the nature and density of the connections between elements within practices, and regarding the extensiveness and interconnectedness of the wider systems of practice in which different commuting variants are embedded. We thus feel that despite some limitations, practice network mapping holds much potential in helping to develop understandings of how to decarbonise practices such as commuting.

Practice network mapping originated through a novel, experimental mode of interdisciplinary collaboration between social scientists and engineers. To conclude, we therefore draw attention to one of the underlying but foundational arguments of this paper, that efforts to reconfigure everyday life and practices for a low-carbon society will demand new and more diverse modes and practices of interdisciplinary collaboration that actively generate novel interactions, insights and interventions into practices such as those related to mobility.

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