Car dependent practices: Findings from a sequence pattern mining study of UK time use data

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ABSTRACT

This paper identifies three main understandings of the notion of 'car dependence' in transport research: a *micro*-social understanding (dependence as an attribute of individuals), a *macro* approach (attribute of societies or local areas as whole), and a *meso*-level understanding, where it refers to trips – or rather to the activities that people travel to undertake. While the first two approaches have been dominant, this paper further develops the third, addressing questions as to whether and why certain activities are inherently more difficult to switch away from the car. At the theoretical level, it builds on theories of social practice to put forward the notion of 'car dependent practices'. At the empirical level, it demonstrates that the application of sequence pattern mining techniques to time use data allows the identification of car and mobility intensive activities, arguably representing the trace of car dependent practices. Overall, the findings of this mining exercise suggest that the emphasis of existing literature on escorting children, shopping and carrying heavy goods as car dependent trip purposes is not misplaced. Our analysis adds to this knowledge by contextualising the information by providing detailed quantitative analysis of a larger, richer set of activities hitherto overlooked in transport policy. The article concludes by illustrating the policy implications of the approach adopted and the findings generated, discussing possible strategies to steer practices in a more sustainable direction by creating material alternatives to the 'cargo function' of car travel.

1. Introduction

Despite wide acknowledgement that current transport patterns in developed countries are major contributors to global environmental externalities such as fossil fuel depletion and climate change, the field of sustainable transport policy remains characterised by a large gap between goals and accomplishments (Bache et al., 2014; Schwedes, 2011). Indeed, transport is the only sector where greenhouse gases emissions have increased from the 1990 baseline in the EU-27 with road transport responsible for 71.7% of them (EC, 2012).

In transport research and policy literature, use of the term 'car dependence' is widespread. At a very general level, it is used to draw attention to the fact that current sustainable transport policies are ineffective in reducing the demand for private motorised travel, that more radical policies are difficult to implement because of public and political acceptability concerns and that the car is deeply ingrained in our societies with consequent social barriers to sustainable transport. Overall,

the notion of car dependence is "(a) testimony of the difficulty of moving away from the car system, despite the increasing awareness of the negative externalities" (Mo.Ve. Association, 2008, p. 3).

Despite this common sentiment, the term is used in a variety of ways in the literature. This co-existence of different meanings has fostered recurrent complaints among scholars that the concept is not properly addressed or defined (Gorham, 2002; Lucas and Jones, 2009; Mo.Ve. Association, 2008). In this paper, it is argued that the discouraging variety of definitions can be better disentangled by drawing on basic sociological concepts (structure, agency, etc.) and that there are in fact only three different understandings of 'car dependence', corresponding to three levels of analysis: *micro* (car dependence as an attribute of individuals), *macro* (attribute of society and/or the built environment) and *meso* (attribute of particular trips, activities or practices). This typology is presented in Section 2. Notably, while the micro- and the macro-understandings have been prevalent so far, they tend to overlook either structural constraints that are external to the individual (micro) or the role of human action in reproducing existing car-oriented structures (macro). Therefore, we argue that it is necessary to further develop a meso-level understanding of car dependence. From a theoretical point of view, theories of (sustainable) social practice, treading a middle course between agency and structure, are a useful resource for this endeavour. They are introduced in Section 3, along with a working definition of 'car dependent practices'. From an empirical point of view, the article demonstrates that the application of quantitative methods (sequence visualization and pattern mining techniques) to large, information-rich datasets (time use data) allows the identification of *activities* that are most likely to be sequenced with car travel. These in turn are taken to represent the trace of car dependent *practices*, as discussed in Section 4. The dataset, data analysis techniques and the software employed are introduced in Section 4 along with the calculation of the car and mobility intensity indices. Section 5 presents the findings of the study based on data from the 2000 British Time Use Survey, which are discussed in Section 6. Section 7 discusses the policy implications of the approach adopted and the findings generated. Section 8 discusses possible future research directions.

2. Car dependence: a typology

Several attempts have been made to summarise existing definitions of car dependence and to create a simple typology (Gorham, 2002; Jeekel, 2013; Lucas and Jones, 2009; Mo.Ve. Association, 2008; Stradling, 2003). However, the variety of competing categorizations is still large. This paper uses these literature reviews as a basis to put forward a very simple typology of *understandings or approaches to the study of* car dependence – in a 'review of reviews' of sorts (Table 1).

The micro-understanding of car dependence is also the most widespread. The distinguishing feature here is that dependence is an attribute of the individual, who is considered to rely or depend on the car with dependence able to be defined from weak to strong (Goodwin et al., 1995; Zhao, 2011). In other words, this approach is concerned with questions of agency (or lack thereof). Typically, however, authors distinguish between two types of car dependence at the micro-level. Farrington et al. (1998, p. 3, quoted in Stradling, 2003), for example, make a distinction between *conscious* (for "those who rely on their vehicle but could realistically undertake their journeys by alternative modes") and *structural* dependence (for "those who are dependent on the car because there are no viable alternatives"). Similar distinctions are found in Lucas and Jones (2009), Anable (2005) and in the Mo.Ve Association report (2008).

'Conscious' dependence is a prime example of what Shove (2010) critically defines as the dominant 'ABC' (attitude, behaviour and choice) paradigm of climate change policy and research: resistance to change is motivated by 'pro-car' attitudes, that prompt individuals to choose car use (behaviour), regardless of other circumstances (availability of other modes, etc.). By contrast, in the case of 'structural' dependence, the problem lies with obstacles to free choice that override the influence of attitudes. While such factors might sometimes be individual attributes (e.g. disability), in most cases they are better thought of as *contextual* or *external* factors. Therefore, the notion of a 'structurally car dependent person' is contradictory and potentially confusing in that the unit of analysis is the individual, while the reasons for dependence are generally attributes of other entities (local areas, institutional timetables, social norms, etc.). While it makes sense to focus on individuals

Table 1
Typology of understandings or approaches to the study of car dependence, based on definitions found in existing literature reviews.

Macro	Physical/environmental car dependence (G)
	Car dependent places (S)
	A car dependent city (M)
	A car reliant location; a car reliant society (LJ)
	Car dependent locations; car dependent times; car dependent societies (J)
Meso	Circumstantial car dependence (G)
	Car dependent trips (S)
	A car reliant trip; a car reliant activity or journey purpose; a car reliant lifestyle; a car convenient journey (LJ)
	Car dependent activities (J)
Micro	Psycho-social car dependence (G)
	Car dependent people (S; J)
	Car reliance of individuals; car dependence of individuals (M)
	A car reliant person; a car dependent person; a car addicted person (LJ)

Legend: G (Gorham, 2002); J (Jeekel, 2013); M (Mo.Ve. Association, 2008); LJ (Lucas and Jones, 2009); S (Stradling, 2003).

to study pro-car attitudes, to understand 'structural' dependence researchers need to use other units of analysis. Therefore, the micro-social understanding of car dependence needs to be complemented by alternative approaches, more suited to shed light on structural constraints that are external to the individual.

The structural factors underpinning car use and making it difficult to bring about change are the main focus of the macro-approach. Dependence is seen here as an attribute of (local) societies, i.e. the focus is firmly on structure, rather than individual agency. While several structural factors have been highlighted (e.g. the need for temporal flexibility in contemporary societies), most research on 'structural' car dependence has focused on the crucial role of the built environment. In the original definition by urban planners Newman and Kenworthy, who popularized the term, there is 'automobile dependence' when "a combination of high car use, high provision for automobiles, and scattered low-density use" (1999, p. 124) leads to "other modes (becoming) increasingly peripheral, marginal or nonexistent until there are no real options for passenger travel other than the automobile" (p. 334). Accordingly, empirical research in this field has defined car dependence as either levels of car ownership and use in the area (Dodson and Sipe, 2007) or the inverse of accessibility to essential services and opportunities with alternative modes (Rendall et al., 2014; Siedentop et al., 2013).

The main blind spot of the macro-approach is that differences in travel behaviour within areas are overlooked, since it is more or less explicitly assumed that "people drive mostly because they have no alternative" (Newman et al., 2009, p. 84). Gorham (2002) for example criticizes the work of Newman and Kenworthy for assuming that the built environment exclusively determines behaviour and failing to recognize the role of individual agency in reproducing and sustaining existing car-oriented social and spatial structures.

Table 1 shows that dependence is also sometimes seen as an attribute neither of individuals nor societies, but rather of trips or related practices and activities. This can be defined as a meso-level approach to car dependence, and it is certainly the least developed in the literature. To be sure, it is generally acknowledged that certain trip purposes are more difficult to transfer away from the car (Stradling, 2003, p. 102). In this context, escorting children and (heavy) shopping (Goodwin, 1995) are often cited, as well as other trip purposes involving the carrying of heavy goods (Jeekel, 2013), such as playing gigs for the freelance string bassist mentioned by Gorham (2002, p. 113). Indeed, even beyond the specific literature on car dependence, there is suggestive evidence that the 'cargo-function' of the car, allowing drivers to carry objects and other people with them, is an important barrier to modal shift, notably for short, shopping, personal business and pick-up/drop-off trips (Kim and Ulfarsson, 2008; Mackett, 2003; RAC Foundation, 2006). The difficulties experienced by public transport riders with encumbrances have been documented (Verbich and El-Geneidy, 2016). Accordingly, the carless find it difficult to carry shopping on public transport and tend to make much of their shopping as car passengers (lifts or taxis) (RAC Foundation, 2006), particularly when they are old (Mattioli, 2014). The physical accessibility problems of mothers travelling with children on public transport, notably for shopping, are also documented (Fritze, 2007).

However, practice-specific factors such as the need to carry objects and dependents have attracted nowhere near the research attention accorded to the influence of attitudes and built environment on travel behaviour. Indeed, a recent comprehensive review of modal choice studies (De Witte et al., 2013) makes no mention of carryability or escorting as possible determinants of car use and, while trip purpose is classified among the factors "often studied and rarely found significant", this might be due to the broad categories typically used (e.g. commuting, business and leisure) which potentially obscure significant differences by lumping together very different practices (Anable, 2002; Anable et al., 2014; Doherty, 2006).

To sum up, we argue that meso-level car dependence is currently under-conceptualised and under-researched. In the next section, we attempt to fill this gap by putting forward a working definition of 'car dependent practices' that is inspired by social practice theories.

3. Car dependent practices

While there is a variety of approaches to the study of social practices (Reckwitz, 2002), an essential common feature is that they turn the assumptions of individualist approaches upside down: while in the latter the individual is the main object of study, in the former practices are the primary unit of analysis and "individuals feature as carriers or hosts of a practice" (Shove et al., 2012, p. 7). Shove et al. (2012) have put forward a deliberately simple understanding of practices as "routinized types of behaviour" (Reckwitz, 2002, p. 249) consisting of three kinds of elements – materials, competences and meanings – which are integrated when practices are performed. In this context, "materials" refers to "things, technologies, tangible physical entities and the stuff of which objects are made", "competences" refers to "skill, know-how and technique" and "meanings" include "symbolic meanings, ideas and aspirations" (Shove et al., 2012, p. 14). The authors also emphasise the importance of taking into account time and space when studying practices. From a dynamic perspective, they argue that "practices emerge, persist and disappear as links between their defining elements are made and broken" (Shove et al., 2012, p. 21).

A certain amount of mobility is an integral part of many practices, as most transport is best conceived as a 'derived demand'. It can be assumed that some of these practices are more car dependent than others. Of course dependence is a question of degree. We can imagine practices involving car use as part of a continuum. At low levels of dependence, the practice can be carried out by car or with an alternative mode, and the other elements (materials, competences and meanings, along with timing and location) are not affected by this change. At high levels, or 'car dependent practices', the car has become the dominant element in the integration between the different elements and modal shift (i.e. the substitution of

car driving with another transport mode) would entail substantial adjustments in the relationship between them. So for example, to shop for food without a car, a person might be required to get new materials (backpack, big thick bags, trolley) and/or to acquire some new skills (e.g. on how many things you can buy in a single round of shopping) and/or to change the frequency and the timing (several episodes of shopping on the way back from work, instead of a single weekly shopping trip on Saturday morning) and/or to change the destination (i.e. a smaller, possibly more expensive supermarket near home rather than the cheap suburban one). In the most extreme case of dependence, the practice may not happen at all if the car is not used.

Crucially, the notion of car dependent practices would allow researchers to take into account and systematically conceptualise aspects that are overlooked by the micro- and macro-approaches:

- The crucial role of *materials*. As illustrated in Section 2, the idea that practices involving the carrying of objects or human beings with a limited capacity for autonomous movement (children, older people, etc.) are more car dependent is a widely held assumption in transport research, for which however there is only a small body of empirical evidence. In the framework proposed by Shove et al. (2012), materials are an essential element of practice and empirical studies have shown that subtracting the car (and therefore objects that cannot be carried to destination without a car) can have serious consequences on the possibility of performing specific practices (Hui, 2012).
- The importance of *competences*. Sometimes the most important barrier to modal shift is the lack of skills, i.e. the need to learn new ways of doing (the same) things. This applies not only to the use of other transport modes per se, but also to the activities performed at the destination. Indeed, the car allows practitioners to bring with them tools that influence substantially how the practice is performed (Hui, 2012) and even when using alternative, more portable tools is possible, this might require different skills (to perform different *variants* of practice). As a result, reluctance to do the same things in different ways might explain car use.
- Negative collective *meanings* associated with certain practices when done with alternative modes (e.g. taking children to school by bike as risky behaviour and 'bad parenting') and/or dissonance between the image of certain travel modes and that of the practice carried out at the destination (e.g. the perception of cycling as a lower-class activity that does not fit with a middle-class job, cfr. Aldred and Jungnickel, 2014).
- *Issues of timing.* Some practices might need to be carried out at another time of day, or with more/less frequency if the car were not available – e.g. weekly 'bulk shopping'. Others, such as bird watching (Hui, 2013a) or flexible working practices (Kent, 2014) have grown to be dependent on the temporal flexibility afforded by the car, allowing practitioners to travel at a moment's notice (Shove, 2002).
- *Change over time.* As the elements of a practice change through new technologies, meanings, etc., the role of the car is likely to change which will, in turn, alter the provisions, norms and further dominance of this mode of transport. This perspective allows questions about how a given practice has come to depend so much on the availability of a vehicle and how the materials, competences and meanings have changed in this transition. From a (sustainable transport) policy perspective, the relevant question is: how is it possible to encourage a new transition in order to break the links between the car and other elements of a given practice?

In the remainder of this paper, we present a quantitative empirical study where time use activity categories are characterised in terms of their mobility and car intensity using innovative sequence analysis techniques. The goal of this mapping exercise is to identify traces of car dependent practices, i.e. areas worthy of further research and policy attention. In doing this – to paraphrase Shove and Walker (2014, p. 16) – our goal is to reinstate fundamental questions about *what car travel is for* in transport research and policy.

4. Methods, data and techniques

4.1. Methods

Investigating thoroughly the competences, meanings and materials involved in a putative car dependent practice arguably requires qualitative methods. This does not mean that quantitative research does not have a role to play. In this paper, we add to a small but growing body of research on social practices that uses quantitative methods (Browne et al., 2014), often applying them to time use datasets (Southerton et al., 2012; Warde et al., 2007) even though, to our knowledge, this is the first study to use sequence analysis techniques and focus on transport.

Of course, this methodological choice is not without implications. First, while at the *theoretical* level we put forward a working definition of car dependent *practices* (Section 3), our choice to conduct secondary analysis means that in the *empirical* study we inevitably have to work with the information that is available, i.e. time use activity categories (*activities* in the following). This is based on the assumption that "uses of time (...) represent the detectable remains or traces of practices" (Shove, 2009, p. 18). However, while information on the respondent's self-reported activities, their location and timing is available in the datasets, we lack data on meanings and materials. Also, the coding of any given activity in this data sometimes corresponds to a disparate array of activities in reality. These challenges are commented on where relevant in the analysis. Second, our definition of car dependence emphasises questions of shiftability, comparing the configuration of elements

of practice when the car is used with a hypothetical modal shift. Ideally, a quantitative study of car dependent practices should be able to investigate this tension directly, similar to studies rooted in the micro- (Zhao, 2011) and macro- (Rendall et al., 2014; Siedentop et al., 2013) understanding of car dependence. However, time use data only allows an investigation of the activities actually carried out. Therefore, our analysis focuses on the degree to which, in the aggregate, different activities are likely to be flanked by car travel in the sequence of activity episodes. To sum up, our empirical study of the car *intensity* of *activities* using time use data is meant to initiate and inform a discussion of the car *dependence* of *practices*, bringing to light areas for further in-depth research and policy intervention. We argue that this is an important task, and one that could not be accomplished with qualitative methods (Browne et al., 2013).

4.2. Data source

The dataset used in this study is the *2000 British Time Use Study*[1] (TUS in the following). It includes information on 19,898 diary days of 10,381 persons (aged 8 years or more) belonging to 6414 households. The sample is representative of the population of individuals in private households in the UK (ONS, 2003).

For the purposes of this study, a time use survey has two crucial advantages over the national travel surveys (NTS) more commonly used in transport research. First, a more fine-grained categorisation of activities, allowing us to detect more meaningful 'traces of practices': there are 265 activity codes in TUS, as compared to only 23 broad travel purposes in the British NTS. This is also the reason why we opted against using the more recent, but less detailed 2005 British TUS (only 30 non-travel activity codes). Second, TUS includes information on all (travel and non-travel) activities carried out on the diary day, assigned to 144 ten minutes slots over a 24 h period (04:00–04:00), rather than on trips only. Two diary days (one weekday and one weekend day) are included for each respondent. This completeness of information is crucial in allowing us to investigate how activities are 'flanked' by mobility and car travel.[2]

4.3. Data analysis techniques

Time use research has traditionally made little use of information about the sequencing of activities, concentrating instead on the aggregate analysis of total activity duration and participation. In contrast, we use the visualization and sequential pattern mining techniques developed by Vrotsou (2010) for the Visual-TimePAcTS software, originally developed as a tool to visualize time use data in accordance with the principles of time-geography (Ellegård and Cooper, 2004). The *ActiviTree* tool allows user-centred exploration of the sequences (Vrotsou et al., 2009), enabling us to explore to what extent sequences of one or more episodes are flanked by (car) travel. In order to investigate also the duration of car travel episodes, as well as to apply the techniques to very large datasets, we have emulated the functions of *ActiviTree* in *Stata*. Arguably, this analytic approach holds promise for the study of practices (Mattioli et al., 2014), as attested by the emphasis of previous theoretical research on sustainable practices on the sequencing of interlinked practices (Shove, 2009; Spurling et al., 2013).

4.4. Calculation of the indices

The empirical analysis presented in this article is based on the calculation of a series of indices assessing the degree to which specific activities are likely to be flanked by (car) travel activities. Fig. 1 shows a simplified representation of the *ActiviTree* output with the activity of interest ('shopping mainly for food') at the centre as well as, branching in and out, the activities preceding and following it (for ease of representation, travel activities other than 'travel by car, van' are grouped together in a single branch, as are other non-travel activities). Based on such output and on further calculations, we calculated the five indices as illustrated in Table 2.

In the next section, the *MI* and *CMS* indices are used to illustrate visually the similarity between activities with regard to the likelihood of being flanked by (car) travel. The last three indices (*CI$_1$*, *CI$_2$*, *CDS*) allow us to provide different answers to the policy-relevant question 'which activities are responsible for a large amount of car travel?' Furthermore, if the assumption is made that car travel duration is a reasonable proxy for the minutes of engine running,[3] and that the contribution of public transport to transport-related CO_2 emissions is negligible (Brand and Boardman, 2008), then arguably *CI$_1$* and *CI$_2$* are proxies for the *carbon intensity* of the activities.[4]

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[1] Ipsos-RSL and Office for National Statistics, *United Kingdom Time Use Survey, 2000* [computer file]. *3rd Edition*. Colchester, Essex: UK Data Archive [distributor], September 2003. SN: 4504.

[2] TUS has been manipulated to facilitate the application of sequence pattern mining techniques. First, we have modified the TUS activity categorisation to distinguish travel activities by travel mode rather than by purpose. The resulting activity category 'travel by car, van' encompasses 'travelling by passenger car as the driver', 'as a passenger' and 'driver status unspecified'; 'travelling by lorry, or tractor'; 'travelling by van'. Second, in the original dataset a new activity episode is reported every time one of the following attributes changes: main or secondary activity, location, accompanying persons. As our analysis has focused on the main activity only, we have collapsed subsequent episodes so that no episode in the resulting datasets is followed by another occurrence of the same main activity. The resulting dataset includes 478,731 episodes.

[3] This assumption discounts the fact that there may be instances of double counting, e.g. when two or more members of the same household share a vehicle.

[4] Information about travel distances and the make and model of the car used – typically absent in time use datasets – would allow a more rigorous modelling of the energy and carbon intensity of activities.
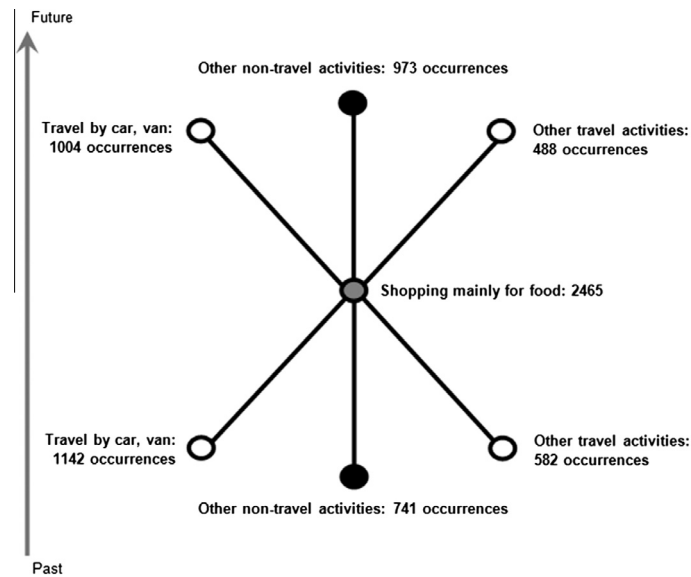
Fig. 1. Simplified representation of Visual-TimePAcTS/*ActiviTree* output: activities preceding and following food shopping. *Source:* TUS, own elaboration.

A common limitation of the above indices is that they only take into account (car) travel episodes *directly* flanking episodes of the activity of interest. Admittedly, this can give rise to distortions if other activities are slotted in between travel and the activity that is travelled to, or if travellers chain different transport modes. These limitations will have to be addressed in future research efforts.

5. Findings

5.1. British Time Use Study

Based on the original TUS dataset, a new dataset has been constructed with 236 activities as cases and the indices described in Section 4.4 as variables. This quite literally addresses the recommendation of practice theory to take practices, rather than individuals, as the unit of analysis. The analysis illustrated in this section has focused on a subsample of 55 activities, obtained by sequentially excluding: (i) travel, unspecified time use activities and activities with an unweighted number of episodes lower than 100; (ii) activities with below the average (44.6%) proportion of episodes taking place out of home. The 55 activities and relative codes are listed in Table 3, which can be used as a look-up table.

Fig. 2 shows the location of the activities in a bi-dimensional space where *CMS* is the *x*- and *MI* the *y*-axis. Interestingly, regression analysis shows that the relationship between the two indices is not statistically significant at the 0.05 level ($r = 0.235$, $n = 55$, $p = 0.08$), suggesting that all combinations of the two indices are equally likely. It also shows that the large majority of activities (41) have a car modal share higher than 50%. The top 20 activities with the highest car modal share are highlighted in Fig. 2 and discussed in the following. 19 of them have a higher car modal share than 'working time in main job' (at place 20).

Perhaps unexpectedly, the single activity with highest *CMS* is 'disposal of waste'. This is defined as removing waste "from the dwelling *and its environs*" in the survey (ONS, 2003, p. 152) and therefore should not include disposal activities that entail no travel but are within the home, such as door-to-door pick up and arranged collection of items.[5] This suggests that, *when people have to travel to dispose waste*, car use is overwhelmingly predominant (90%), perhaps because of the inaccessible location of recycling centres or the bulkiness of the items being removed.[6] Indeed several activities in the top 20 (different types of shopping, 'outdoor pairs or double games', which includes tennis and golf, 'gardening and pet care as help',[7] 'accompanying child' and 'walking the dog') suggest the co-presence of travelling with heavy items, dependents or pets.

'Walking the dog' is a prime example of an activity with very low *MI* (presumably because it inherently involves walking mobility) but very high *CMS*, suggesting that there might be a minority of people who transport their dogs by car before

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[5] We are grateful to Isabella Capurso for raising this point to us.

[6] Another possible explanation is the sequencing of disposal of waste with 'shopping and service' activities, possibly related to the location of recycling stations in or near supermarkets. Further analysis suggests that this effect exists but is not dominant, as CMS values for 'shopping and services' activities are way below 0.9 (see below), and they account for only 21% of non-travel activities following 'disposal of waste'.

[7] The TUS activity categorisation includes several categories of 'informal help to other households', defined as "direct help given by the respondent to another household, and not arranged by an organisation" (ONS, 2003, p. 163).

Table 2
Indices used in the analysis of TUS.

Index	Acronym	Interpretation	Formula	Notes
Mobility Intensity	MI	The likelihood that the activity is flanked by transport activities	$MI = (T_b + T_a)/(2A - A_1 - A_l)$	MI ranges between 0 (the activity of interest is never flanked by travel activities) and 1 (it is always flanked on both sides[a])
Car Modal Share	CMS	The likelihood that, *when the activity is flanked by transport activities*, it is flanked by car travel	$CMS = (C_b + C_a)/(T_b + T_a)$	CMS ranges between 0 (i.e. when the activity of interest is flanked by travel activities, these are exclusively alternative modes) and 1 (all travel activity episodes flanking the activity of interest consist of car travel[b])
Car Intensity index 1	CI_1	The average minutes of car travel flanking the activity of interest	$CI_1 = TDC_i/(A - A_1/2 - A_l/2)$	CI_1 is proportional to the product of MI, CMS and the average duration of the car travel episodes flanking the activity of interest ($CI_1 = 2 * MI * CMS * MDC_{im}$)
Car Intensity index 2	CI_2	The average minutes of car travel flanking the activity of interest *for every minute of the activity of interest*	$CI_2 = CI_1/MDA_{im}$	This variant takes into account the fact that different activities of interest have different typical durations, and these tend to be proportional to the time spent travelling to them
Car duration share	CDS	*Proportion* of total duration of all car travel episodes in the dataset flanking the activity of interest	$CDS = TDC_i/TDC$	CDS ranges between 0 (no car travel episode flanks the activity of interest) and 1 (all car travel episodes flank it), and is proportional to the cumulated duration of the episodes

Key:

A – number of episodes of the activity of interest

A_1 – number of occurrences of the activity of interest that are the *first* episode in the diary day sequence

A_L – number of occurrences of the activity of interest that are the *last* episode in the diary day sequence

T_b – number of travel activity episodes – *before* episodes of the activity of interest

T_a – number of travel activity episodes – *after* episodes of the activity of interest

C_b – number of car travel activity episodes – *before* episodes of the activity of interest

C_a – number of car travel activity episodes – *after* episodes of the activity of interest

TDA_i – total duration of all the episodes *of the activity of interest*

TDC – total duration of all car travel episodes in the dataset

TDC_i – total duration of the car travel episodes *flanking the activity of interest*

MDA_{im} – mean (average) duration of an episode of the *activity of interest* ($MDA_{im} = TDA_i/A$)

MDC_{im} – mean (average) duration of the car travel *flanking the activity of interest* ($MDC_{im} = TDC_i/(C_b + C_a)$)

[a] The formula takes into account the fact that all diary day sequences are censored at 4:00 by having $2A - A_1 - A_l$ instead of $2A$ in the denominator.

[b] There is not necessarily any relationship between MI and CMS, as CMS can assume any value between 0 and 1 when $MI \neq 0$. See Fig. 2, Section 5.1.

walking them, perhaps to reach 'nice spots' beyond walking distance. Another example is 'gardening and pet care' where, besides the challenges of transporting pets with other transport modes, one might suspect that the tools and objects involved in gardening practices (plants, etc.) tend to be transported by car, possibly due to their size and weight. This would explain high CMS, suggesting that where mobility is involved, it is highly car dependent. Low MI suggests that the mobility involved in 'gardening and pet care' might often not be directly sequential to the activity itself and so it is not picked up in this index. Finally, the presence of several 'help' activities might be interpreted as proof of the fact that having to escort others is a factor behind high CMS, while it is not immediately clear why both 'organisational' (volunteer) work activities included in the analysis sample are also among those with the highest car modal share.

At the other end of the spectrum, among the activities with the lowest CMS one finds two study activities, 'classes and lectures' (code 2110 in Fig. 2) and 'other specified activities related to school or university' (2190). This might be explained by the fact that only individuals over the age of 8 are included in TUS and this possibly reflects the travel patterns of autonomously mobile, but carless teenagers and university students. High CMS values for 'accompanying child' suggest that the school run of younger children might be more car oriented, as confirmed by recent travel figures for England (DfT, 2014). Interestingly, 'free time study' (2210, including e.g. artistic and language courses), which is more likely to be performed by adults, has a radically different profile with CMS higher than 60%. This difference is likely to be overlooked when education is analysed as a single travel purpose as in the NTS. One might also speculate about the existence of a small cluster of low CMS activities including 'other specified social life' (5190, including being together with friends in places such as pub, club and cafeterias), 'gambling' (7340), 'billiards, pool, snooker and petanque' (7321) and 'other specified games and play with others' (7329, including cards and other board games).

Interestingly, among the activities with the lowest CMS there are also physical exercise activities such as 'biking' (6131) and 'outdoor team games' (6144, including ball games such as football, rugby and cricket). This contrasts with the fact that

other sports rank among the activities with the highest car modal share (Fig. 2). These include notably 'outdoor pair and double games' (6143), 'fitness' in centre/gym (6160), 'swimming' (6171) and long walks and hikes (6111). As a result, Fig. 3 shows that the means-centred 86% confidence ellipses drawn around the eight physical exercise activities in the sample covers a much larger area than that around the ten shopping and services activities, clustered at relatively high levels of *MI* and *CMS*.

Despite the relatively more homogeneous profile, a closer look reveals variation among shopping and services activities. Fig. 4 'zooms in' by showing truncated Mobility Intensity (0.5–0.75) and Car Modal Share axes (0.5–0.9). The size of the hollow circle markers is proportional to the total duration of the car travel episodes flanking the activity (TDC_i). While food and 'unspecified' shopping activities account for a large part of shopping and services-related car travel, the outlier 'shopping mainly related to accommodation'[8] is responsible for a non-negligible amount of it, partly as a result of high *MI* and *CMS*. At the other end of the spectrum, 'commercial and administrative services' (including visiting post office and bank) and 'window shopping' (with no aim of buying) have much lower car modal shares. In light of the 'cargo function' hypothesis discussed above, it is tempting to suggest that there is a positive relationship between the bulkiness of the objects putatively involved in the activity and *CMS*, with letters and envelops ('commercial and administrative services') and clothes presenting less need for carrying capacity than shopping bags full of food or furniture.

In order to explore the 'cargo function' hypothesis more in-depth, we have focused on the household upkeep activity 'various arrangements' including, among other things, "arranging purchases". When 'various arrangements' is preceded by travel activities, the activities most likely to precede this 2-tuple (i.e. sequence of two episodes) are unspecified and food shopping, lending some credibility to the hypothesis that, when sequenced after shopping and travel, 'various arrangements' mostly consists of arranging purchases. Based on this assumption, we have elaborated and tested two hypotheses:

- the types of shopping most likely to involve a large amount of goods are more likely to be followed by arranging purchases upon returning home. This is confirmed as, while on average 15% of 2-tuples of 'shopping'-'travel' are followed by 'various arrangements', this varies greatly between 'shopping for clothing' (2%) and food shopping (27%), $X^2(6, N = 6151) = 281.34$, $p < 0.01$,
- when there are many purchases to arrange (enough to be reported in a ten-minute slot), car use is more prevalent. This is also confirmed as car modal share is higher in 3-tuples of 'shopping'-'travel'-'various arrangements' (72%) than in 2-tuples of 'shopping'-'travel' (59%), $X^2(1, N = 6151) = 61.61$, $p < 0.01$.

These findings provide initial exploratory evidence in support of the cargo function hypothesis, and demonstrate the added value of sequence pattern mining techniques in exploring how activities bundle together and constrain each other.

In the remainder of this section, we focus on three further indices (CDS, CI_1, CI_2), that allow us to provide different answers to the policy-relevant question as to which activities are responsible for a large amount of car travel. As illustrated in Section 4.1, these indices constitute proxies for their car and carbon intensity.

Fig. 5 shows the 15 activities with the largest amount of car travel flanking them (CDS). The graph shows clearly the exceptional status of 'working time in main job', accounting for roughly 25% of the total duration of car travel flanking all activities in our sample. However this also means that, despite the strong transport policy focus on the journey to work, three quarters of car travel duration *does not* directly precede or follow employment episodes. The list also includes several activities which, despite their relatively low CMS, are responsible for a large amount of car travel as a result of their high frequency of occurrence in the dataset ('visiting and receiving visitors', 'other specified social life', 'classes and lectures'). High frequency is also the reason why 'walking the dog' appears in this list, despite low mobility intensity, a clear sign that the amount of car travel associated with pet practices is far from irrelevant. Unsurprisingly, numerous activities that appeared in the top 20 of *CMS* in Fig. 2 also appear here, including several categories of shopping and services and 'accompanying child'.

Fig. 6 lists the 15 most car intensive activities, with car intensity here defined as the average amount of car travel (minutes) *per episode* (CI_1), and shows a rather different picture. Interestingly, most activities in Fig. 6 are more car intensive than employment according to this measure (although this might be due to the fact that working days are typically constituted by sequences of working time and other activities, resulting in lower *MI*). Also, several activities that did not particularly stand out in the previous analysis are prominent here, including 'shopping or browsing at car boot sales or antique fairs',[9] 'sports events', 'other specified entertainment and culture', 'visiting a leisure park', 'feasts' (including weddings and funerals) and 'cinema'. This suggests that long average duration of the car travel episodes flanking them (i.e. longer distances) is the main reason for high car intensity. For instance, car boot sales typically take place in out of town fields difficult to access by modal alternatives – although *CMS* for this activity is not particularly high (cfr. Fig. 2), suggesting that where the car is used, it is for long journeys. Finally, the graph shows that several high *MI* and high *CMS* activities (Fig. 2) such as shopping and services, 'accompanying child' and 'outdoor pairs or double games' are also characterised by high car intensity using this index.

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[8] The following examples are provided in the activity coding list: "bought plants for the garden; looked at an apartment for sale; shopped at DIY store; was at estate agents" (ONS, 2003, p. 173).

[9] Car boot sales are a popular form of market in the UK where private individuals gather to sell household and garden goods.

Table 3
Activities retained for the analysis, with activity codes. *Source:* TUS.

Code	Activity
1110	Working time in main job
1120	Coffee and other breaks in main job
1210	Working time in second job
1310	Lunch break
1399	Other specified activities related to employment
2110	Classes and lectures
2190	Other specified activities related to school or university
2210	Free time study
3250	Disposal of waste
3440	Walking the dog
3610	Unspecified shopping
3611	Shopping mainly for food
3612	Shopping mainly for clothing
3613	Shopping mainly related to accommodation
3614	Shopping or browsing at car boot sales or antique fairs
3615	Window shopping or other shopping as leisure
3619	Other specified shopping
3620	Commercial and administrative services
3630	Personal services
3840	Accompanying child
4110	Work for an organisation
4120	Volunteer work through an organisation
4210	Food management as help
4220	Household upkeep as help
4230	Gardening and pet care as help
4240	Construction and repairs as help
4250	Shopping and services as help
4271	Physical care and supervision of a child as help
4273	Reading, playing and talking to the child as help
4281	Physical care and supervision of an adult as help
4290	Other specified informal help
4310	Meetings
4320	Religious activities
5120	Visiting and receiving visitors
5130	Feasts (e.g. weddings/funerals)
5190	Other specified social life
5210	Cinema
5250	Sports events
5294	Visiting a leisure park
5295	Visiting an urban park, playground or designated play area
5299	Other specified entertainment or culture
6111	Talking a walk or hike that lasts at least 2 miles or 1 h
6119	Other walk or hike
6131	Biking
6141	Indoor pairs or double games
6143	Outdoor pairs or doubles games
6144	Outdoor team games
6160	Fitness
6171	Swimming
6190	Other specified physical exercise
6311	Activities related to sport
7321	Billiards, pool, snooker or petanque
7329	Other specified parlour games and play
7340	Gambling
7390	Other specified games

Fig. 7 is based on a different understanding of car intensity, i.e. the amount of time spent travelling by car *per minute spent on the activity* (CI_2). Interestingly disposal of waste is the single most car intensive activity here, with on average more than 8 min of car travel per 10 min spent disposing of waste. The absence of this activity from Fig. 6, despite extremely high *CMS* (Fig. 2) suggests that, while the duration of car travel episodes flanking disposal of waste is not very long per se, it is disproportionately long relative to the typically short duration of the activity. The same is arguably true for shopping and service activities, accounting for 9 out 15 activities in Fig. 7. Further exploration shows that shopping and services activities have on average a very high ratio of travel duration (one-way) to activity duration, notably if compared to other types of activities, suggesting that often the time spent travelling to shopping and service activities is longer than the time spent at the destination – a factor crucially contributing to high car intensity.
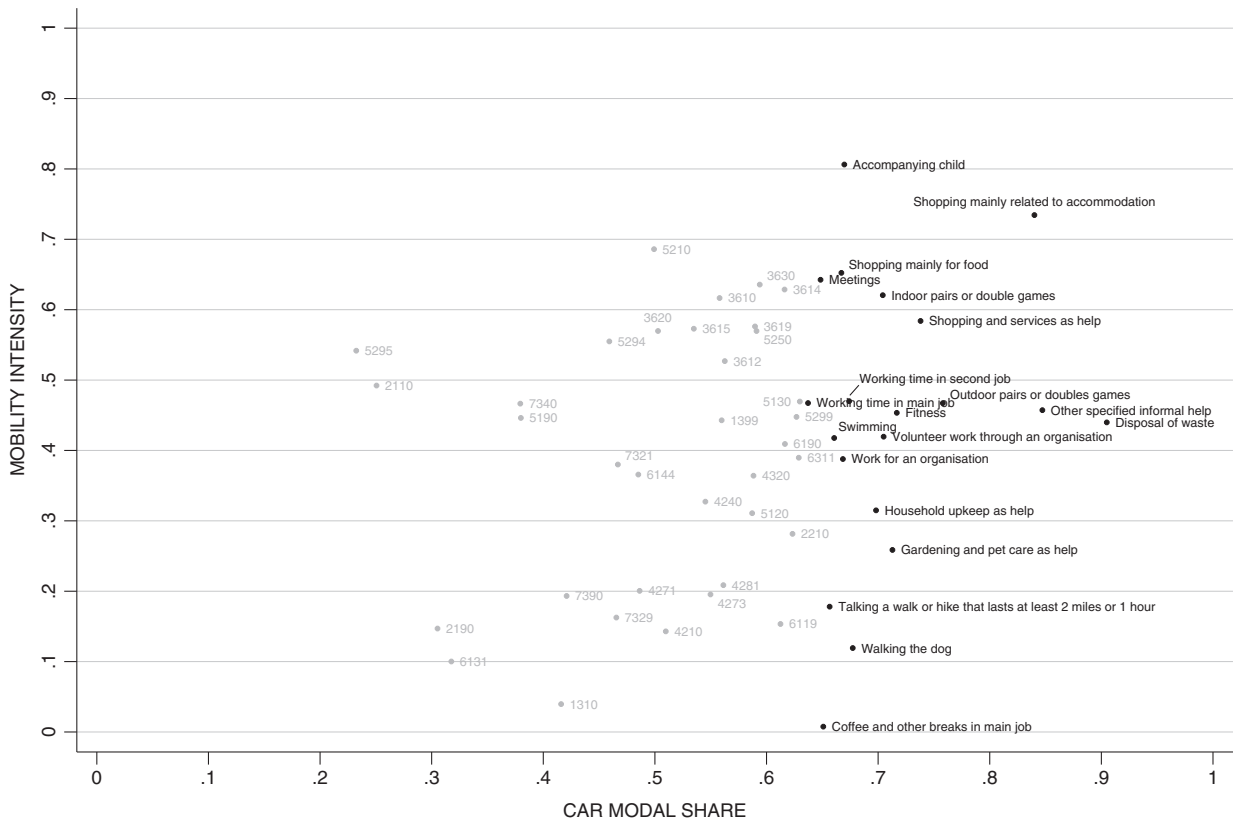
Fig. 2. Mobility intensity and car modal share for the analysis subsample. *Legend:* See Table 3. *Source:* TUS, own elaboration.
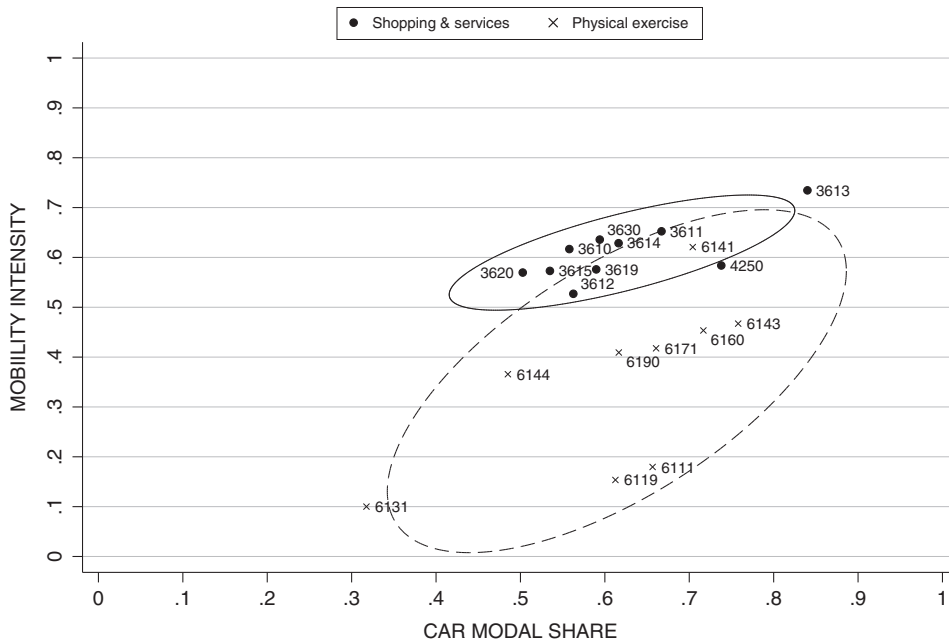

Fig. 3. Mobility intensity and car modal share for shopping and services and physical exercise activities, with confidence ellipses. *Legend:* See Table 3. *Source:* TUS, own elaboration.
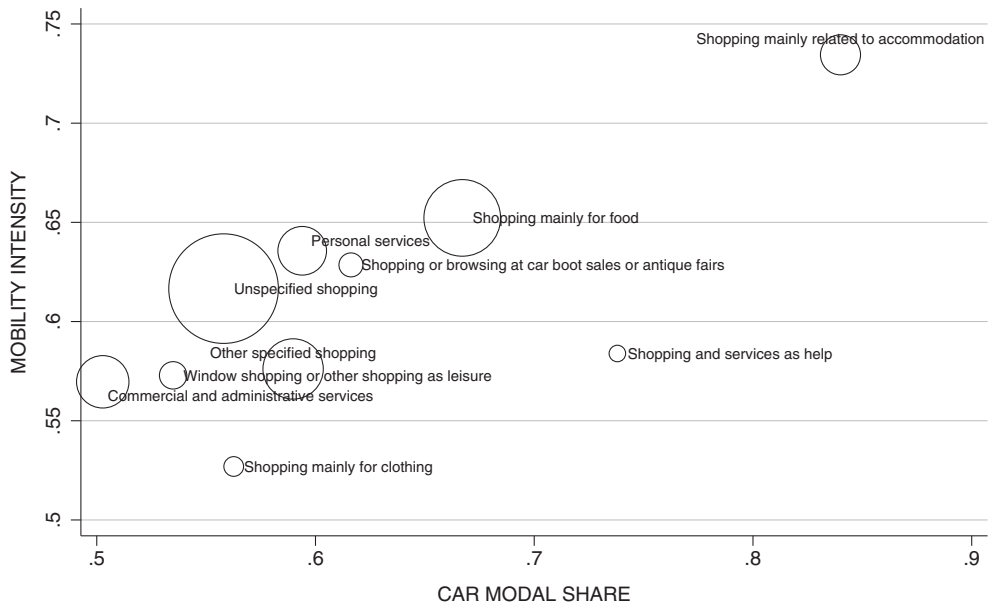
Fig. 4. Mobility intensity, car modal share and total duration of car travel flanking shopping and services activities. *Note*: the size of the hollow circle markers is proportional to the total duration of the car travel episodes flanking the activity (TDC_i). *Source:* TUS, own elaboration.
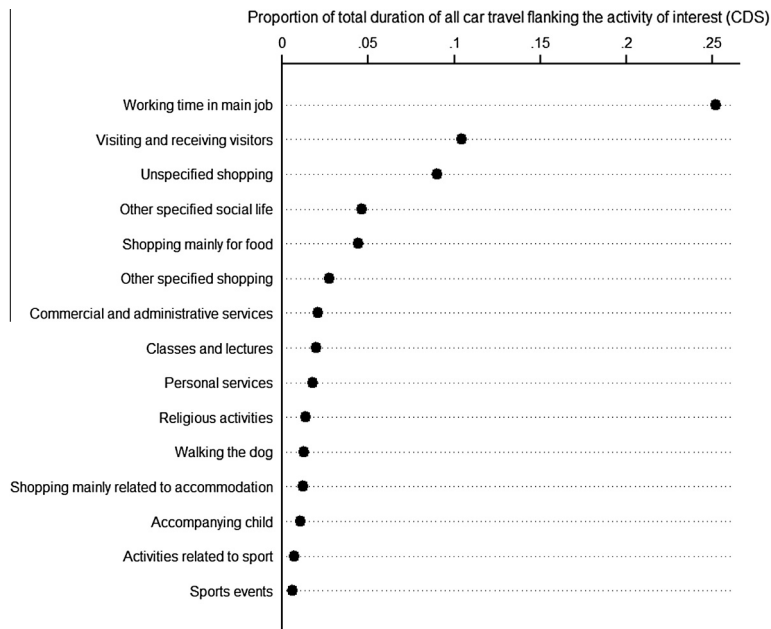

Fig. 5. Top 15 activities by proportion of total duration of all car travel flanking the activity of interest (*CDS*). *Source:* TUS, own elaboration.

Overall, Figs. 6 and 7 draw attention to a fairly limited set of activities which, while less frequent overall than employment, can be thought of as being particularly car intensive, for reasons that have to do with high car modal share and/or the distances typically travelled. Particularly notable is the fact that shopping and services activities are in the top 15 in terms of total travel duration (Fig. 5) as well as in both understandings of car intensity.

6. Discussion

The well-established macro- and micro-approaches to car dependence need to be complemented by a *meso*-approach based on recent developments in theories of social practices. While there have been repeated calls to introduce a social
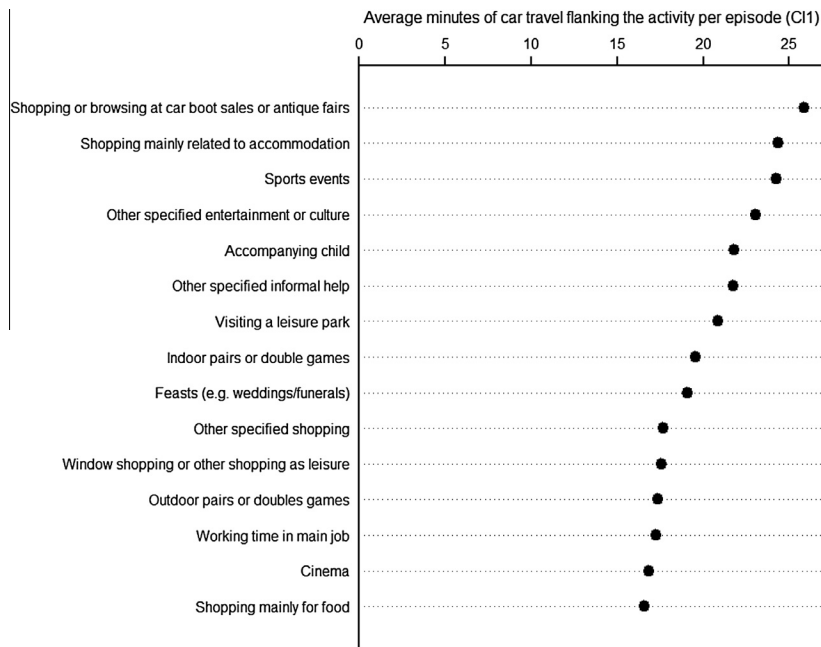
Fig. 6. Top 15 activities by car intensity (index 1) (CI_1): average minutes of car travel flanking the activity per episode. *Source:* TUS, own elaboration.

practice approach in transport research (Watson, 2012; Cairns et al., 2014), most studies so far have either focused on car driving, cycling and car sharing as practices per se (Aldred and Jungnickel, 2014; Bartiaux, 2013; Kent and Dowling, 2013; Shove et al., 2012; Watson, 2012) or tried to link concepts of mobility (broadly defined) and social practices (Hui, 2012, 2013a, 2013b). In contrast, in Section 3 we have sketched a theoretically rich notion of 'car dependent practices' to highlight that, while a certain amount of mobility is an integral part of many practices, some of these might be more car dependent than others.

Also, while Cairns et al. (2014) argue that one of the factors limiting the impact of sociological contributions on transport policy and research is that they are not often tested using quantitative techniques, we have demonstrated that detailed and widely available time use survey data can be exploited with innovative sequence analysis techniques in order to single out activities that are strongly associated with car travel. Clearly, the secondary analysis presented in the previous section cannot directly address all of the nuances of social practices. What it can do, however, is to bring to light traces that are discussed in this section in light of the full repertoire of concepts introduced in the theoretical section.

Whilst our findings support those in the existing literature which identifies escorting children, shopping and carrying heavy goods as car dependent trip purposes, our analysis adds to this knowledge by placing it within a bigger picture. Time use data allows us to provide detailed quantitative analysis of a larger, richer set of activities hitherto overlooked in transport policy. Several activities stand out from this analysis as sitting at different points on the spectrum of car dependent practices introduced in Section 3.

At one extreme, the disposal of waste is the single most car intensive activity in relation to the time spent undertaking it (as well as the one with the highest car modal share). This might be interpreted as the result of the inaccessible location of at least some waste recycling facilities, but also suggests that the removal of the car from this activity would alter the practice of waste disposal to such an extent it would alter the practice itself. It also highlights the serious consequences of a lack of integrated policy making between transport and other sectors. While the arguments for integrating transport and land-use development policies are well-rehearsed (Kaufmann and Sager, 2006; Newman and Kenworthy, 1999), the side-effects of poor integration with other sectors of public policy (such as waste collection) largely remain to be explored.

While one could argue that walking the dog is not inherently car dependent per se, our analysis shows that 'driving the dog to walk', even though a relatively minority practice (Fig. 2), is a relevant contributor to total car travel (Fig. 5), due to high rates of dog ownership and high car modal share.[10] This finding, along with high car modal share for 'gardening and pet care as help', adds to recent research findings from the domestic sector showing how pets can contribute to increased energy consumption (Strengers et al., 2014). Clearly, this may be the case for transport as well and poses a challenge to previous research that has focused on walking the dog as a beneficial physical exercise activity in light of health and obesity concerns (Cutt et al., 2007).

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[10] Walking the dog is the thirtieth most frequent activity in the TUS dataset (out of 236), with 2708 occurrences in 19,898 diary days.
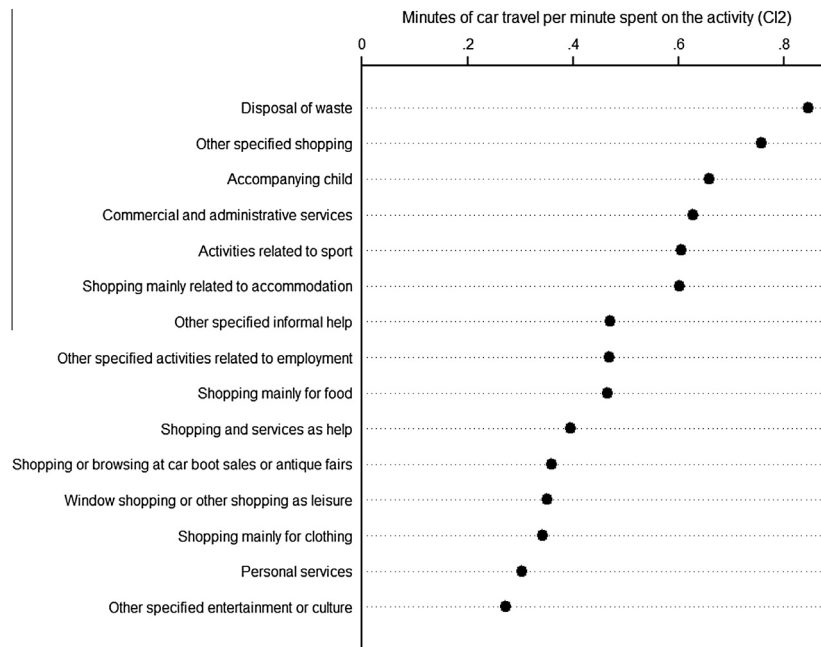
Fig. 7. Top 15 activities by car intensity (index 2) (CI_2): average minutes of car travel flanking the activity of interest for every minute of the activity of interest. *Source:* TUS, own elaboration.

The wide variation of car modal share levels for physical exercise activities illustrated in Fig. 2 is difficult to interpret without more in-depth studies, but might be explained by differences in the system of provision at the local level (i.e. the location of sport facilities or hiking destinations), the need to carry materials (e.g. golf clubs, tennis rackets) as well as dissonance with the class distinctions typically associated with certain sport activities (e.g. golf, cfr. Bourdieu, 1979) and the persistent perception of modal alternatives as low class pursuits (Aldred and Jungnickel, 2014). This highlights the role of the different meanings attached to activities that at first sight may seem very similar. What this tells us is that the details of doing, e.g. the type of sport people travel to, matters a lot for modal choice – a fact that is arguably poorly taken into account by the broad-brush activity categorisations commonly used in transport research and policy (Doherty, 2006). For instance, the British NTS includes five distinct categories for shopping and services (which appear to be more similar according to our analysis), but only one for 'sports: participate', clearly obscuring a considerable amount of variation.

Overall, the approach has demonstrated the value of focusing on the details of 'what people travel to'. Taken as a whole, the results can be interpreted as a challenge to the persistently strong transport policy focus on the journey to work as, through the use of different measures, this paper has highlighted a range of activities that deserve more policy attention. In the next section, the implications of adopting a practice approach for transport policy making are illustrated.

7. Policy implications: an illustrated example

Much transport policy and planning is currently driven by the principles of random utility maximization (Cirillo and Xu, 2011; Hensher et al., 2005). These are used for example in discrete choice models to forecast mode choice and route choice, with this information feeding into cost-benefit analysis for the appraisal and evaluation of transport policies and schemes (van Wee, 2012). An essential assumption behind this paradigm is that individuals rationally weigh up the costs and benefits (both temporal and monetary) of what they do and make travel decisions accordingly. In the context of sustainable transport policy, this leads to an emphasis on initiatives that increase the costs of car travel (e.g. road pricing) or reduce the costs of alternatives (e.g. public transport infrastructure developments).

The macro- and micro-approaches that are dominant in car dependence research result in different policy focuses. The emphasis on attitudes in the micro-approach has inspired soft transport policy measures such as travel awareness campaigns and personalized travel planning programs (Anable, 2005; Bamberg et al., 2011; Cairns et al., 2008; Möser and Bamberg, 2008). The emphasis on the effects of the built environment on travel in the macro-approach is clearly related to compact city policies, spatial planning measures and sustainable street design (De Vos and Witlox, 2013; Newman and Kenworthy, 1999; OECD, 2012).

The meso-approach to car dependence that we propose in this article comes with a different set of policy implications, as it highlights how car use can get locked in by elements of the practice which go far beyond a person's ability to exercise a

rational choice, as well as beyond attitudinal and built environment factors. The remainder of this section illustrates these policy implications.

The implications of adopting a practice approach for sustainability policies have been discussed before (Shove et al., 2012; Spurling et al., 2013), also in the transport field (Hui, 2013b; Watson, 2012). The agreement is that, rather than a generic one-size-fits-all approach, a wide range of interventions targeted at specific practices is warranted. However, in order to avoid being overwhelmed by the huge variety of everyday practices, it is necessary to identify priorities and areas of particular concern. In this context, we agree with Hui (2013b) who argues that sustainable travel policies should be "tailored to particular, travel-intensive practices" with "small targeted projects that attend to specific practice-mediated patterns of travel" (p. 99). The present article contributes to this endeavour by bringing to light areas of interest.

Two main findings of the present study are the importance of the 'cargo function' of car travel, which highlights the crucial role of the materials involved in the practices at the destination, and, relatedly, the relevance of shopping practices, which stand out according to virtually all of the measures employed in Section 5. One way of looking at this is to assume that these activities are simply too difficult to shift to other modes and that it is better to concentrate efforts elsewhere. Our point of view, however, is that the cargo function of the car has not been adequately conceptualised and investigated yet, as it does not fit either 'mainstream' approaches to transport modelling, nor macro- and micro-level understandings of car dependence. In contrast, the meso-level approach proposed in this article allows the elements of a practice to be 'seen' and therefore a better assessment of how practices might be steered away from car dependence. To demonstrate this, in the remainder of this section, we discuss possible strategies to address the cargo problem and steer shopping practices in a more sustainable direction. The goal is to provide an illustrated example of the kind of policy measures that come into focus when adopting a practice-oriented approach to car dependence.

With respect to the cargo function of travel, it is possible to think about interventions that would take the material side of shopping practices as a site of intervention, with the goal of encouraging a shift towards alternative travel modes. Research in the field of consumer studies has shown how objects such as shopping carts (Cochoy, 2008) and bags (Cochoy et al., 2014) crucially constitute the way in which shopping is carried out. Accordingly, sustainability designers focus on the identification and removal of barriers to the recruitment into more sustainable practices (Clune, 2010), imagining for example the introduction of carefully designed shopping trolleys, backpacks and panniers to allow people to shop for food without a car (Calvignac et al., 2014). Indeed, recent research suggests that material arrangements such as shopping trolleys play an important role in the transition to a life without a car (Bartiaux, 2013).

Similarly, there are currently several programmes in Europe testing the introduction of cargo bikes (Lenz and Riehle, 2013), including the EU-funded project CycleLogistics (2011–2014). While the main focus of the project has been on urban freight and courier services, it has also included shop-by-bike campaigns aiming to "demonstrate to the population that bicycles are often the most efficient vehicle to transport shopping goods or leisure time equipment (and) determine the infrastructural requirements and services for customers that shop by bike at the supermarkets and shops" (Wrighton, 2012, p. 4). Indeed, private cargo bike use is a reality in cities like Copenhagen (Gössling, 2013) and there is a vibrant global grassroot network of cargo bike users and makers (Lennon, 2011), suggesting the possibility of a successful linking of top-down and bottom-up efforts.

The substitution of travel to the shops with online shopping and home delivery (as well as with other emerging practices such as e-books and 3D printing) has been discussed as a way of reducing its environmental impacts. However, the benefits of such a substitution are intensively debated, with studies showing that, for a single purchase (and depending on numerous assumptions), home delivery is less carbon intensive than travelling to the shops (Edwards et al., 2010), but at the level of individuals and households, e-shopping seems to have a complimentary, rather than a substituting effect on physical travel (Cao et al., 2012). On a more general point, this solution does not involve a proper modal shift, but rather a different, possibly more efficient organisation of the transport of purchased goods by car/van.

With regard to public transport, previous studies on shopping travel have acknowledged that a modal shift would require "creative solutions to the problems of carrying heavy and awkward goods (on the bus)" (RAC Foundation, 2006, p. 3). Currently, local buses do not typically have storage space for bags and luggage (except for services running to airports). However, in recent years, great efforts have been made to provide buses and tramways with spaces for wheelchairs, to improve accessibility. As a result, public transport providers might be reluctant to sacrifice further seating space for shopping bags. On the other hand, low occupancy rates of vehicles at off-peak times mean that there is a considerable amount of space that could be made available, possibly using innovative solutions such as folding chairs.

Car sharing is currently in rapid expansion in urban areas worldwide, even though it is currently still a small fraction of all car use. Car sharing is thought to result in reduced car ownership and overall car use, and is often presented as a way to fill in "the gaps left by the limited carrying capacity (of) alternative modes" (Kent and Dowling, 2013, p. 87). However, car sharing models often provide small vehicles whose suitability for carrying large amounts of stuff is questionable. While one might argue that larger vehicles should be offered alongside the small ones, this would result in increased emissions (all other factors equal), highlighting an interesting trade-off.

Overall, a practice approach to the shopping cargo problem would try to intervene simultaneously on all elements of practice (Spurling et al., 2013), with the goal of generating positive feedback processes that might ultimately result in socio-technical transitions (Watson, 2012). In this context, it must be remembered that policy initiatives intervene on "processes that already have a life on their own" (Shove et al., 2012, p. 156) and that innovations that map onto broader societal trends are more likely to be successful (Kent and Dowling, 2013). In that sense, there is much to be gained from identifying

and harnessing interesting developments in areas related to shopping. While some of these developments have been mentioned in the above, others include the gradual phasing out of lightweight plastic bags in the EU (potentially disrupting previous routines), increasing use of shoulder bags and backpacks (Cochoy et al., 2014), the rise of packaging-free shopping (Zero Waste Europe, 2014), the diffusion of bike sharing and the 'return' of retail to the city centre (RAC Foundation, 2006), including furniture outlets that were thought to be inherently bound to suburban locations (Zang, 2014).

Finally, practices can change also as a result of changes in the population of people who perform them (Watson, 2012). From this perspective, the decline in car ownership and use among young adults in several industrialised countries (Kuhnimhof et al., 2012) might signal the rise of alternative carless shopping and carrying practices, making the young carless a group of particular interest as a target for both policy initiatives and future research.

Overall, the policy implications that arise from adopting a meso-level, practice-oriented approach to car dependence are completely different from those arising from mainstream, utility-based approaches to travel behaviour research, but also from micro- and macro-approaches to the study of car dependence. Our illustrated example of shopping practices identifies points of intervention, such as e.g. the objects and tools involved in transporting shopping goods, which are typically not taken into consideration in sustainable transport policies. This is helpful in a context where there is growing acknowledgement of the large gap between the goals and accomplishments of sustainable transport policy (Bache et al., 2014; Schwedes, 2011) and of the shortcomings of current research and policy approaches in tackling car dependence (Handy and Clifton, 2001; Hickman, 2015; Holden and Norland, 2005; Naess et al., 2014; Shove, 2010; van Wee, 2012).

8. Directions for future research

The study presented in this article aims to open up directions for future research on car dependent practices, rather than putting a definitive word on it. In Section 6, we have discussed some explorative findings, providing a tentative interpretation based on existing literature. The activities highlighted as having a high car modal share (e.g. disposal of waste, certain types of sport, etc.) could be the object of further in-depth research. Only this could confirm the hypotheses put forward here to explain the patterns observed in the time use data.

In this context, it would be interesting to investigate the dynamic relationships between car dependent practices and car ownership. It is possible that the commitment to certain activities (e.g. those related to dog ownership) is an overriding factor in whether a household owns a car in the first place, as well as on which type of car they own (e.g. in relation to the size of the boot, etc.). Given the strong relationship between car ownership and use (Simma and Axhausen, 2001; Van Acker and Witlox, 2010), as well as between vehicle make and model and polluting emissions (Chatterton et al., 2015), the knock-on implications of participation in car dependent practices could be important and worth exploring.

The relationships between the macro-, micro- and meso-levels of car dependence have not been addressed in this article, but they are another interesting direction for future research. Notably, the dynamic and self-reinforcing interactions between the macro- and meso-level appear worthy of further investigation. For example, in cities where shopping has concentrated into 'big box' retail and out-of-town shopping malls, this likely increases the meso-level car dependence of shopping trips. Conversely, retailers specialising in goods that are typically transported by car might have no incentive to choose locations that are accessible by alternative modes. While such relationships are beyond the scope of this article, we believe that the establishment of a theoretical and empirical approach to car dependent practices, which is the goal of this study, is an indispensable preliminary step in this direction.

Another area of future investigation is the longitudinal and cross-country comparison of the car modal share and mobility intensity of time-use activity categories. The metrics and techniques developed in this study could be applied to the Multinational Time Use Study (MTUS), an internationally harmonised dataset which currently encompasses over 60 datasets from 25 countries and covers the period between the 1960s and 2015. This would allow the investigation of longer term trends in international comparison, something which is harder to do with travel survey data, given the historical lack of harmonisation (Hubert et al., 2008). Such an analysis could bring to light country-specific trends in the car intensity of specific activities, identifying areas where further exploration of the elements which make up these practices (materials, competencies and meanings) may help to explain the changes over time and space. This would help address the questions about change over time that we have set out in Section 3. Notably, tracing historical trends in the 'mobility intensity' of activities may help address questions concerning the substitution of 'corporeal travel' by ICT developments such as online shopping, e-books, 3-D printing, etc.

Acknowledgements

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