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Assessing the energy implications of replacing car trips with bicycle trips in Sheffield, UK

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ABSTRACT

A wide range of evidence supports policies which encourage people to cycle more and drive less, for health and environmental reasons. However, the likely energy implications of such a modal shift have remained relatively unexplored. In this paper we generate scenarios for increasing the cycling rate in Sheffield between 2010 and 2020. This is done through the novel application of a simple model, borrowed from population ecology. The analysis suggests that pro-cycling interventions result in energy savings through reduced consumption of fuel and cars, and energy costs through increased demand for food. The cumulative impact is a net reduction in primary energy consumption, the magnitude of which depends on a number of variables which are subject to uncertainty. Based on the evidence presented and analysed in this paper, we conclude that transport policy has a number of important energy implications, some of which remain unexplored. We therefore advocate the formation of closer links between energy policy and transport policy in academia and in practice; our approach provides a simple yet flexible framework for pursuing this aim in the context of modal shift.

1. Introduction

Increasing the proportion of trips made by non-motorised transport in urban areas is desirable from environmental, health, and natural resource perspectives (Michaelowa and Dransfeld, 2008; Killoran et al., 2006; Woodcock et al., 2007, 2009; Dodson and Sipe, 2005). However, widespread awareness has so far failed, in most places, to transfer into effective policy action: cycling and walking still constitute a small proportion of trips in all but a few developed countries, and non-motorized transport has yet to pose a serious threat to the dominance of the car in the vast majority of urban settlements (Pucher and Buehler, 2008). This knowledge–policy gap has widened recently with the publication of evidence which strengthens the argument for political action on climate change, degenerative diseases, and oil depletion (IPCC, 2007; Barness et al., 2007; Aleklett et al., 2010).

Although these intractable problems have received much academic attention, the recommended solutions often tackle just one area, such as climate change adaptation or obesity drugs, at a time (Klein et al., 2007; Nature News, 2006). Such narrow 'solutions' could be effective if policy-makers faced a series of isolated problems, but instead, the issues relating to modal shift are interrelated aspects of a wider global predicament (Greer, 2008). For this reason, broad analyses tend to recommend integrated policies which tackle many issues simultaneously (e.g. Odum and Odum, 2001; Beddoe et al., 2009). Converting this theory into practice has proved challenging, however, the appropriate policy measures remain the subject of intense debate (Jackson, 2009). Reducing fossil fuel demand in developed countries, however, is one objective which receives support from a wide range of perspectives and is increasingly central to mainstream political priorities (e.g. Smil, 2008; Woodcock et al., 2007; Perman, 2003). This objective, and the evidence which supports it, provides a conceptual basis for this paper.

Transport is the fastest growing energy user globally and the sector consumes over 20% of primary energy supply; this is primarily due to car use (Smil, 2005). The conventional car is an exceptionally inefficient form of urban transport, typically consuming 2.9 MJ of fuel per person-km (pkm) if the driver is the sole occupant (MacKay, 2009, Fig. 20.23). Cyclists, by contrast, consume around 80 kJ/pkm of food, less than 1/30th of the primary 'fuel' requirements of cars. In developed economies, where car ownership has approached one car for every two people (World Resources Institute, 2009), the driver is often the car's sole occupant. In the

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UK, for example, 38% of car journeys are single occupancy and the average occupancy has fallen from 1.64 to 1.60 between 1985 and 2008 (DfT, 2003, 20008b). Cars consume 74% of the diesel and petrol, and 10.6% of total primary energy supplied to the UK.[1] This prodigious use of primary fossil energy entails a wide range of negative consequences which can be mitigated by replacing car trips with less energy-intensive forms of transport.

This paper therefore analyses the energy implications of a modal shift. Energy-intensive transport is linked with a range of environmental, social and economic consequences such as greenhouse gas emissions, transport inequality and dependence on finite resources. However, reports evaluating transport policy often fail to see the common thread of energy running through each of these problems, focussing instead on individual metrics such as CO_2 emissions, metrics of psychological health, or economic return (e.g. Åkerman and Höjer, 2006; Barton and Pretty, 2010; Sloman et al., 2009). Energy implications, which cut across, and to some degree encapsulate, environmental, social and economic metrics, may provide a more holistic guide to policy-makers than individual impacts and allow for more integrated decision making. Energy is the 'master resource', so minimizing energy wastage may be the best way to benefit all aspects of well-being simultaneously. But why investigate the energy implications of car to bicycle shifts (as opposed to other transport shifts)? The reasons are as follows: First, this shift may offer the greatest energy saving of any voluntary change in transport behaviour, in the short term.[2] Second, bicycle policies can be implemented rapidly during times of economic hardship, as they do not require the complex and capital-intensive structures demanded by motorized alternatives. Third, cycling is roughly five times more efficient and three times faster than walking, offering a far greater range of mobility for the same amount of time and effort (Komanoff, 2004; typical speeds of cyclists and walkers are 15 and 5 kph respectively). Fourth, policies to facilitate the car to bicycle shift are being rapidly implemented in many towns across the UK (Sloman et al., 2009) and the world (Dennis and Urry, 2009) so deserve attention. Finally, the modal shift from cars to bicycles exemplifies the multiple social purposes that can be served through policy aims framed as being about transport and energy. The narrow focus of transport planning on economic growth is now shifting towards more pluralistic aims (Banister, 2008; DfT, 2008a), and this is reflected in the wide range of places where modal shift policies are being implemented (Pucher et al., 2010). Because research into the energy implications of modal shift could be relevant in a wide range of locations, the methodology is presented in a generalised way that is easy to replicate. Many cities undergoing modal shift could have been used for this study. However, Sheffield is of particular interest as it is a hilly city with a low, but rapidly rising rate of cycling. Such case studies are rare in the cycling literature, which tends to focus on flat cities, with an already high cycling level. As a prominent Sheffield-based cycling advocate put it: "if cycling can work here, it can work anywhere in the world" (Bocking, 2010, personal communication).

The broad aim of this paper is to illustrate some of the veiled links that connect transport policy and energy use. The 'vehicle' used to illuminate these links is a quantitative analysis of the energy implications of a car to bicycle modal shift in Sheffield by 2020, which is developed and discussed in the following sections: After a brief description of Sheffield's current transport practices (Section 2), a model is used to provide three scenarios for the cycling rate in Sheffield by 2020 (Section 3). The resulting output is then analysed (Section 4), and discussed (Section 5) to explore the energy implications of the modal shift for each of the three scenarios.

The model we use for projecting cycling rates originates in the field of population ecology and was selected in response to the "need for simple, yet not primitive, easily applicable urban transportation models" (Supernak, 1983, p. 79). The model is simple (defined by only two parameters), flexible, and directly applicable to important concepts in transport planning such as carrying capacity and intermodal competition (see Section 3). While econometric models of transport choice (e.g. Hensher, 1985; Whelan, 2007) are frequently used and useful for identifying economic factors influencing transport behaviour, they were not suitable for this paper due to their lack of an innate time dimension, reliance on price assumptions, and complexity. The model was used to project the cycling rate in 2020 under different policy scenarios, with mode (cycling in this case) analogous to 'species' and trips made per year analogous to 'individuals' in population ecology. The three scenarios modelled in this way are referred to throughout the paper as: business as usual (BAU), a 'do nothing' baseline; hard pro-cycling policy (H), a purely engineering approach; and integrated pro-cycling policy (I), the most ambitious scenario which combines the engineering approach of scenario H with additional soft (non-engineering) measures. Details of how the model was calibrated and modified to create each scenario are provided in Section 3.

1.1. Previous research on the energy implications of modal shift

The energy requirements of motorized transport modes have been quantified on numerous occasions (Lenzen, 1999). However, the energy requirements of non-motorized transport have received far less attention (Coley, 2002), and the wide-boundary energy implications of shifts from one mode to another have not been quantified at all in the literature reviewed.

The complex relationships between energy use, transport and health are explored by Woodcock et al. (2007), who project that significant reductions in CO_2 emissions (and hence energy use) would result from a shift to non-motorized transport forms in London. The benefits would be multifaceted (including the indirect energy-saving effects of reduced obesity rates, number of traffic accidents, and dependence on fossil fuel companies), and could apply to rich and poor countries alike. However, much of this analysis is speculative, and the energy-saving potential of modal shift is not quantified. Ramanathan (2005) estimates the potential energy savings of a road to rail modal shift: if 50% of road trips could be replace by rail in India, his model suggests a 35% net reduction in energy use could be achieved. Such scenario-based studies are less common at the city level, however, and the energy costs and savings of car to bicycle shifts is new academic territory. Generalized models of energy use in transport have however been developed, which can be applied in a wide range of circumstances.

Climate change mitigation provides a motive for many recent transport-energy use studies. Åkerman and Höjer (2006) produce 'images' of the Swedish transport sector in 2050. Their analysis suggests that drastic cuts in energy use and associated emissions are only possible if behavioural and technological measures are pursued in parallel. Fels (1975) presented a generalized equation for calculating the total energy requirements of different transport

[1] In 2008, the UK consumed 22,709 million litres of motor spirit (petrol in the UK, gasoline in the US) and 25,686 million litres of diesel (DECC, 2009), or 727 PJ and 991 PJ respectively. Cars consumed 95% of the UKs motor spirit, and 36% of the UKs diesel (DECC, 2009), a total fuel consumption of 1050 PJ. Total UK primary energy consumption in 2008 was 9840 PJ in the same year (DECC, 2009); cars consumed 10.6% of this.

[2] Carbon rationing, flight quotas, and increased fuel taxes may offer greater energy benefits, but these are not voluntary.