A multi-level analysis of sustainable mobility transitions: Niche development in the UK and Sweden

Björn Nykvist a,⁎, Lorraine Whitmarsh b

Stockholm Environment Institute (SEI) and Stockholm University, Department of Systems Ecology, 106 91 Stockholm, Sweden
Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK

ARTICLE INFO
Article history:
Received 7 May 2007
Received in revised form 22 January 2008
Accepted 27 May 2008

Keywords:
Sustainable Mobility
Transition
Regime Change
Niche Development
Innovation

ABSTRACT
A wide range of intractable problems such as polluting emissions, noise, accidents, resource depletion, and inaccessibility of amenities are associated with the current transport regime. Given the slow movement towards a more sustainable mobility system, more radical, systemic innovation – a ‘transition’ – is required. Broadly speaking, this may be achieved via three routes: technological change, modal shift, and reduced travel demand. Drawing on concepts from the transitions literature (e.g., [Geels, F.W.: Technological Transitions and System Innovations: A Co-evolutionary and Socio-Technical Analysis, Edward Elgar, Cheltenham, 2005.]), we conceptualise each of these routes as a bundle of niche activities within an Area of Innovation, deviating to differing degrees from the current mobility ‘regime’. We present empirical evidence and indications of ongoing development of niches in these three areas within the UK and Sweden, and explore processes of co-evolution, divergence and tension within and between niches. Findings indicate recent market penetration of novel transport technologies, more advanced than modal shift or demand management activities; however, different transport technologies are more successful in each country. We also identify examples of a close relationship between development of radical vehicle/fuel technologies and provision of mobility services; and information technology as a driver in all three areas of innovation. We conclude that future innovation in transport depends on diversity, hybridisation, and co-evolution of niches. Finally, policy implications are discussed.

© 2008 Elsevier Inc. All rights reserved.

1. Introduction

Our current road-based land transport systems suffer from a number of intractable problems. These include congestion, emissions of greenhouse gases and local air pollutants, noise, accidents, depletion of resources, and inaccessibility of amenities and services (e.g., [1]). For example, transport is the sector with the highest increase of greenhouse gas emissions in recent decades, rising within Europe by 24% between 1990 and 2003 [2]. Given these problems, and their associated economic, social and environmental impacts, the current mobility system may be considered in many respects unsustainable.

Although the notion of ‘sustainability’ is contested and different criteria are emphasised by different groups [1,3,4], broadly speaking sustainable mobility is understood to contribute to social and economic welfare, without damaging the environment or depleting environmental resources. For example, the World Business Council for Sustainable Development defines ‘sustainable mobility’ as ‘the ability to meet the needs of society to move freely, gain access, communicate, trade, and establish relationships without sacrificing other essential human or ecological values today or in the future’ [5]. The various dimensions of ‘sustainable mobility’ may be grouped under social, economic and environmental pillars of sustainability (see Table 1).
Table 1
Dimensions of sustainable mobility according to SUMMA project

<table>
<thead>
<tr>
<th>Economic outcomes</th>
<th>Environmental outcomes</th>
<th>Social outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility</td>
<td>Resource use</td>
<td>Accessibility and affordability</td>
</tr>
<tr>
<td>Transport operation cost</td>
<td>Direct ecological intrusion</td>
<td>Safety and security</td>
</tr>
<tr>
<td>Productivity/efficiency</td>
<td>Emissions to air</td>
<td>Fitness and health</td>
</tr>
<tr>
<td>Costs to economy</td>
<td>Emissions to soil and water</td>
<td>Liveability and amenity</td>
</tr>
<tr>
<td>Benefits to economy</td>
<td>Noise</td>
<td>Equity</td>
</tr>
<tr>
<td></td>
<td>Waste</td>
<td>Social cohesion</td>
</tr>
</tbody>
</table>

*SUMMA [4] (Sustainable Mobility, policy measures and Assessment) was funded by the EC (DGTRN) 2002–2005. The project aimed to define and operationalise sustainable transport, and to assess the contribution of EC policies for tackling transport problems and promoting sustainable transport in Europe. See: www.summa-eu.org.

In this paper, we contend that there has been an over-emphasis on the former aspect of sustainable mobility (namely, provision of mobility to meet primarily economic ends) to the detriment of the latter consideration (that is, environmental and social well-being). We therefore focus on innovations that – to different extents – may redress this imbalance and offer more environmental and social benefits than exist in the current transport system configuration.

To date, policy measures to foster more sustainable mobility by influencing individual travel decisions (e.g., congestion charging, vehicle taxation) have had little effect relative to the underlying growth in demand. The benefit of technical measures to reduce vehicle emissions and noise has often been outstripped by the increase in vehicle numbers, engine size, travel frequency and trip length [6]. It is therefore increasingly recognised that incremental technological or policy improvement may be insufficient to address this type of persistent problem. Instead, radical, systemic innovation – a ‘transition’ (e.g. [7,8]) – is required to move away from the current land-based transport regime and towards a more sustainable mobility system. Studies that have considered possible sustainable mobility transitions highlight the need for both technological and institutional changes (e.g., electric and fuel cell vehicles, customised mobility, teleworking, zoning policies) to achieve a radical reconfiguration of transport systems for sustainability [9,10]. In this paper, we consider three broad approaches to tackling unsustainable transport and achieving the criteria outlined above:

1. improving efficiency and reducing the impact of vehicles (primarily through improvements to existing vehicle technologies, development of radical new vehicle or fuel technologies);
2. using more sustainable modes of travel (increased use of public transport and slow modes, but also changes in how modes are utilised);
3. reducing the need to travel (through urban planning, mobility management, lifestyle change and increased use of Information and Communication Technologies (ICT)).

We use the emerging body of literature on ‘transitions’ to frame our investigation of innovation in sustainable mobility systems within two European countries: the UK and Sweden. We aim to explore the progress, and assess trends that foster and counter niche development and innovations in a broader sense. The paper is organised as follows: the next section describes the relevant theoretical concepts (e.g., transition, regime, niche, niche-accumulation, and areas of innovation) we use to frame our research; while Section 3 describes our methodology. Section 4 analyses the current regime in more detail; Section 5 then discusses results of our investigations into potential transitions to sustainable mobility. Finally, Section 6 summarises our analysis, discusses implications for theory and policy, and suggests areas for future research.

2. Theoretical background: multi-level perspective, niches and areas of innovations

Transitions researchers have developed the multi-level perspective (MLP) as an analytical frame for the empirical study of radical socio-technical innovation (Fig. 1). This perspective highlights three functional levels – ‘niche’, ‘regime’ and ‘landscape’ – with increasing structuration and coordination of activities, ranging from individual technologies and grassroots movements to larger-scale social structures and institutions. The regime has been described as the dominant ‘culture, structure, and practices’ [11] or ‘dominating practices, rules and shared assumptions’ [7]. In recent work, Geels and Schot [12] refer to ‘cognitive routines’, ‘regulations and standards’, and ‘adaptations of lifestyles to technical systems, sunk investments in machines, infrastructure and competences’. Previously, Geels [99] suggested seven components that make up a regime: technology, infrastructure, techno-scientific knowledge, markets and user practices, cultural and symbolic meaning, sectoral policy, and industry. Although the precise definitions vary, the essential regime concept is the same. Rules embedded in the elements above provide orientation and coordination, creating stability and cohesion of societal systems. The regime guides the actors within to optimise the current system through incremental change, using the capabilities and resources of dominant players. System innovation, or radical change, is restricted since the rules, structures, and culture are manifest in slowly changing regulation, prevailing norms and worldviews, and practices draw chiefly on existing competencies and past investment. Patterns of behaviour are locked in and result in path dependencies for technological and social development [13].

At the micro-level, niches have been identified in historical empirical studies of transitions as the typical loci for radical innovation, operating at the periphery of, or outside, the dominant meso-level regime. A niche can comprise new technologies, institutions, markets, lifestyles and cultural elements and consists of networks of actors/organisations (e.g., [14]). The macro-level
comprises a landscape of changing economic, ecological and cultural conditions, in which the regime may be more or less well-suited to fulfil its functions. As this landscape changes, the regime may experience stress and is typically slow to adapt, whereas niches more quickly evolve. The gradients within the socio-technical landscape determine how easy or difficult particular changes are to bring about [12].

Niche development is central in understanding many types of socio-technological transition [13]. This includes ‘niche-accumulation’, ‘technological add-on’, and ‘hybridisation’. Niche-accumulation refers to the gradual growth of niche applications in different niches, before emergence in mass markets or mainstream society (e.g., [15]). Technological add-on and hybridisation are the processes of new technologies physically linking up with existing established technologies, enabling a smooth transition from one technological option to the next. An example is steamships, which first developed as hybrids between steam and sail technologies [13]. In our study, however, we try to expand the use of the niche concept in the applied multi-level perspective, recognising that the important processes in a transition described above are manifested not only in niches organised around a specific technology. Innovations in policy instruments, new functionalities, and innovative use of existing technologies also form important niches activities (see for example Loorbach for a recent use of niches in this sense [11], p.20). The transitions literature also highlights the importance of ‘pathway technologies’, which ‘help bridge the gap between the current regime and a new (sustainable) one’ ([9], p.158). For sustainable transport, pathway technologies might include emerging information technologies for automatic vehicle control, global positioning, booking and reservations, monitoring for mobility management, and congestion charging; that is technologies associated with important behavioural and institutional changes (e.g., new user practices, standards and regulations). In addition to technological hybridisation, such behavioural and institutional change is involved in these niche development processes [15]. In this article, we explore these institutional, behavioural and technological components of niche development in our analysis of pathways for sustainable mobility, and therefore focus our analysis to ‘areas of innovation’ containing several types of niche.

In particular, we identify three promising areas of innovation, each consisting of several niches and their development — ‘radical vehicle/fuel technologies’, ‘products-to-services shift’, and ‘mobility management’. Each may contribute to the sustainable development of land transport and will be defined in detail in Section 4. We are specifically concerned to explore:

1. indications of the growth of these areas of innovation, trends fostering and countering such a development and whether these suggest a possible ongoing transition to sustainable transport;
2. the qualitative processes of niche development, including ‘niche-accumulation’ and ‘hybridisation’, as well as areas of divergence and tension within these areas of innovations.

3. Methodology

Drawing on the literature outlined in Section 1 and findings from initial stakeholder exercises [3], we have defined three broad areas of radical sustainable mobility innovation. This process was part of the Scoping and Envisioning stages in the MATISSE project¹, later feeding into modelling being published elsewhere. The choice of our three areas is emergent from this exercise, but the final decision is nevertheless normative and it should be pointed out that different boundaries for the three areas could have been used. At the end of the article we discuss the implications of this particular choice.

The areas of innovations are articulated in Section 5, which also presents evidence and indications for their development. Our analysis draw on secondary data and documentary analyses to explore various transport indicators and policies within Europe, focussing on the last two-three decades and on two member states: the UK and Sweden. Time and resource constraints limited the

¹ MATISSE was a European Commission 6th framework project during 2005–2008 A series of working papers available at http://www.matisse-project.net describes the process developed in this project.
study to these two countries. Nevertheless, they represent diverse spatial, cultural and political contexts in which to explore the development and uptake of potential sustainable mobility niches. The UK has a much higher and denser population – and transport network – than Sweden: UK population is around 60 million, while Sweden has a population of around 9 million; yet citizens in both countries travel about the same distance on average each day (30 km) [16]. Politically and culturally, Sweden has embraced sustainable mobility more forcefully than the UK, while UK transport policies have prioritised tackling congestion. Our choice of case studies also represents a new context in which to consider the potential for a sustainable transport transition, since previous research on this topic has primarily focussed on the Netherlands [15]. We have restricted our investigation to land transport because niche activities offering possible alternative behaviours, technologies and institutions have already begun to emerge, therefore offering the greatest scope for investigation.

Our analysis is based on a thorough literature review and secondary data analysis of relevant sources detailing mobility influences and indicators. In particular, we build on the analysis conducted by Skinner [17], which reviews the key trends and influences on mobility demand, and extend this to consider indicators for (technological and behavioural) mobility innovation. A summary of the key trends – and their impact on each area of innovation – is given in Table 7 in the Conclusion section. Thus, our analysis has focussed on identifying trends that support and mitigate development of the three areas of mobility innovation we have defined above. National and European-wide data relating to transport indicators (e.g., demand, modal split) were obtained from Eurostat, and supplemented where necessary from electronic national statistics archives [18,19]. Vehicle sales data and data on the development of alternative fuels was obtained from European Automobile Manufacturers Association [20] and national sources. Where not cited explicitly these include for Sweden: Bil Sweden [21], Swedish Association of Green Motorists [22] and Miljöfordon [23]; and for the UK: the Vehicle Certification Agency [24], and ‘What you can do’ website [25]). Complementary short personal communications with experts were conducted in a few cases to obtain data on aspects of niche development that are poorly documented in the literature or statistics. Finally, we conducted an analysis of key national and European policy documents and reviewed the literature on transport technologies, behaviour and policy.

4. Landscape development and regime dynamics

4.1. Landscape influences on the mobility system

Overall, mobility demand in Europe is rising. Although increases in road traffic demand have varied over the past decades, the long term trend shows no evidence of any reduction in demand (see Table 2). This demand increase is due to important landscape developments such as: increasing households and population (particularly as people live longer and more often live alone); increasing incomes (with more being spent on travel and car ownership); participation of women in the labour force (increasing the commuter population); and increases in speed and convenience of travel [17]. Business-as-usual macro-trends for travel demand within Europe suggest increases are likely in the future as GDP continues to rise [26]. These landscape trends tend to reinforce the regime, and mitigate against the development of mobility management niches.

On the other hand, environmental problems – notably climate change, air pollution, and resource depletion – are emerging as landscape changes that encourage actors to seek more radical mobility solutions. There are also indications that social attitudes and values are changing with widespread awareness of problems associated with transport [27] and concern about environmental issues including pollution and climate change [28,29]. Environmental issues are apparently becoming an important issue next to traditional values such as freedom and economic growth. As Table 2 above indicates, there is so far no evidence that these changes in attitudes translate into behaviour change. As will be discussed in more detail in the following sections, car ownership are issues including pollution and climate change [28,29]. Environmental issues are apparently becoming an important issue next to traditional values such as freedom and economic growth.

<table>
<thead>
<tr>
<th>Year</th>
<th>Billion pkm the UK</th>
<th>Billion pkm Sweden</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>309.5</td>
<td>80.3</td>
</tr>
<tr>
<td>1994</td>
<td>425.6</td>
<td>96.6</td>
</tr>
<tr>
<td>2004</td>
<td>502.5</td>
<td>106.7</td>
</tr>
</tbody>
</table>
Finally, other landscape trends also influence the transport system and innovations therein. Some scholars indicate that the shift from cars to ICT as the dominant socio-technical system has already commenced: while the automobile was the defining cultural icon of the 20th Century, the computer and related technologies are now in the ascendant [36, 37]. The automotive industry is very mature, characterised by fierce competition, fully-exploited economies of scale, and low profitability; the ICT sector, however, is continuing to expand, exploring new products, functionalities, and markets. In fact, much of the technological development in the automotive industry in recent years has been a result of integration of information technologies within vehicles. Cars are still the dominant socio-technical system within the transport domain, but their iconic status is no longer evident. This development is also consistent with continued trends of urbanisation, with urban lifestyles less dependent on individual transport, and in particular more closely aligned with ICT than with car ownership. In the sections that follow, we will look for indications that these ICT-promises are actually having an impact on the potential for sustainable transport.

4.2. The mobility regime

As discussed in Section 2, previous definitions of a ‘regime’ indicate key components are: technologies, industry, infrastructure, policy, user behaviour and culture. Here, we outline the main characteristics of these components, while the following two subsections explore innovations evident along the technological (Section 4.3) and policy (Section 4.4) dimensions. The prevailing mobility paradigm constitutes a regime locked in to a stable state of oil- and car- dependence, dominated by the practice of personal mobility. Infrastructure, manufacturing, and consumer behaviours enforce this regime. As mobility demand continues to rise, and road based transport maintain its regime status through a number of processes. In relation to infrastructure, the built environment has co-evolved alongside personal motorised transport, so that amenities and workplaces are often only accessible by car. Vehicle manufacturing has developed along ‘technological trajectories’ [38], which constrain the development of vehicle and fuel technologies to the development of core competences, particularly in internal combustion engine (ICE) and Budd-type steel chassis [39]. As mentioned, within wider society, too, there is considerable resistance to changing behaviour to more sustainable forms [40]. Driving is not only perceived to be the most convenient and is often the cheapest form of transport, it is also tied to social values and identity [41]. In the UK, for example, there is a widespread association between car ownership and ‘having a good lifestyle’ [32]. This is despite public recognition of the need to tackle rising congestion and other transport problems [27]. In Sweden, Nilsson, and Küler [42] find similar patterns in the literature describing values attached to cars in Sweden. It has also been shown that public acceptance of road pricing among car owners in Sweden decreases if it is perceived as limiting freedom [43]. Much of the inertia in the transport system may be attributed to deeply entrenched habits of car use [30]. Due to these psychological, technological and institutional dependencies, there is typically widespread resistance to radical change [10].

4.3. Regime technological innovation — incremental change

However, the automotive and energy industries, has recently undergone change – reflecting the development in wider society – towards recognition of landscape pressures described above. During the last three decades, all major car firms have begun investing in more environmentally-benign vehicle and fuel technologies, first in catalytic converters, three-way catalysts, and more recently alternative fuel and propulsion technologies. By the mid-1990s patents relating to environmental innovations accounted for around 45% of the total R&D of Japanese automotive firms, representing a higher proportion of investment than quality- and safety-related innovations [44]. Analysis of patents by fuel type show all automotive firms have been focussing primarily on hydrogen and methanol [45]. This picture of a strong trend of R&D geared toward environmental innovations is, however, not true for the whole automotive sector. In particular, the recent trend of larger cars (e.g., SUVs) tells a story of a regime with diverging practices. Indeed, the transport remains the most troublesome sector in terms of CO2 emissions, and the automotive industry in Europe have been reluctant to accept binding targets from more efficient vehicles. As shown in Table 3, the result is an increase in CO2 emissions over the past decades within both Sweden and the UK.

4.4. Regime policy innovation — responding to landscape pressures

The regime traditionally shows a preference for technological solutions to environmental and sustainability problems – the so-called ‘techno-fix’ approach – both within the industry and in policymaking. These purport to offer economic as well as environmental benefits – a win–win outcome [46], a standpoint that avoids the more challenging issue of changing consumer behaviour. More recently transport policy has moved beyond concerns about vehicle emissions [47] to consider a broader range of environmental, economic and social dimensions of mobility such as energy and resource use in manufacturing, and ‘liveability’ for citizens [10, 39]. Although EU transport policy has historically focussed on liberalisation and harmonisation of transport, mobility

| Table 3 |
|------------------|------------------|
| CO2 emissions from road based transport 1990–2005 |
| (Column 1) | UK | Sweden |
| CO2 emissions since 1990 | | |
| For all sectors | −5.6% | −8.5% |
| For road based transport | +10% | +11% |

Source DEFRA for the UK [102] and SEPA for Sweden [103]. NB-For UK the total (‘all sectors’) excludes land use and forestry.
has recently become one of the six priority areas of the EU’s Sustainable Development Strategy [6]; and the European Commission’s White Paper on the Future Common Transport Policy [1] highlights a range of initiatives necessary for tackling problems of unsustainability in the transport sector. Yet despite these encouraging signs, sustainability is still not a dominant concern in European policy-making; rather, the ‘jobs and growth’ agenda continues to be prioritised over environmental (and to some extent social) concerns.

In Sweden, transport policy is similarly now embracing sustainability as an aspiration [35]. Traditionally, safety has probably been the most prominent policy transport issue in Sweden, with the two car manufacturers Saab and Volvo being pioneers in safety innovation, and ambitions policy goals in place. Other key concerns addressed within transport policy over the last decade include accessibility, social inclusion, and environmental impacts including a green tax reform from income to carbon emissions [48]. Sweden is, however, heavily dependent on the vehicle manufacturing industry with two car producers (Ford owned Volvo Cars and GM owned Saab) and two truck producers (Volvo and Scania) within a relatively small country. For this reason, and in order to avoid unpopular measures to reduce demand and increase costs, policies are centred on development and introduction of new technologies and moderate fuel tax increases.

In the UK, there has also been a change, at least in political rhetoric, away from road building and towards introduction of demand management initiatives (see Section 5.3). Yet, there is arguably a lack of genuine commitment to reducing demand for fear of alienating the ‘motoring majority’ [49,50] and reluctance to regulate demand through fuel taxation, in the wake of the 2000 fuel duty protests, which resulted in the government removing the fuel duty escalator. Thus, the government has tended to prioritise measures to tackle congestion (e.g., ‘intelligent highways’, carpooling, and road pricing particularly on new inter-urban roads [51]) rather than politically less popular measures to mitigate climate change and improve accessibility. Indeed, spending on road construction and maintenance has recently increased to £4.4 bn in 2005–6 (of a total £17 bn spent on UK transport during that period) [52].

4.5. Intra-regime dynamics and conflict

There are further indications that the regime is changing in response to landscape pressures. The transitions literature indicates that the niche and regime may exist in either a symbiotic or competitive relationship. In response to landscape pressures, regime actors may draw on niche expertise/innovations if they are unable to adequately respond with their own resources [8]. Other niche practices and technologies are less compatible with those of the incumbent transport regime, and are therefore resisted or opposed by some or all regime actors. A closer look at the transport regime highlights that this is not a homogeneous group of actors; there are variations over jurisdictions and in some cases, interests have become misaligned in response to landscape pressures. For example, while major automotive firms are investing in ethanol vehicles, the natural gas and oil industries have responded by lobbying the UK government to impose standards in order to constrain and delay ethanol commercialisation. Transport policy responses similarly indicate competing priorities and ambiguity, with more attention currently given to economic and environmental impacts (e.g., costs of congestion and infrastructure, emissions) of transport than social impacts, such as exclusion and community severance (see also Section 5.1). While the regime is adapting in some aspects (e.g., investing in radical vehicle or fuel technologies), new issues are emerging such as conflicting interests over incentives for domestic production of biofuels versus cheaper imports, debate over the potential loss of ecosystem services due to intensified land use, and lock-in to new inefficient

![Fig. 2. Indicative model of compatibility of regime and three identified niches. Primarily area of innovation 1, but also area 2, share many technological niches, actors, activities and values with the regime; while area of innovation 3 constitutes a largely distinct set of actors, activities and values only partially shared with area 2. As will be discussed, areas 1 and 2 also have some potential linkages through actors sharing values on new technologies such as fuel-efficient models or alternative fuels.](image-url)
These examples of tensions are typically a precursor to transition, notably in the case of the transition from horse-drawn carriages to automobiles, where the old regime collapsed completely before a new regime emerged [13].

5. Niche dynamics and development

We have defined three broad areas of innovation for sustainable mobility corresponding to qualitatively different approaches to the problem: 1. improving efficiency and reducing the impact of vehicles, 2. using more sustainable modes of travel, and 3. reducing the need to travel. We have grouped niche innovations together so that they fit these three clusters for convenient analysis, recognising that individual niches within each cluster have certain commonalities (e.g., actors, technologies, values) but also differences. We do not intend to trivialise these differences, but simply to produce a useful framework in which to analyse developments in mobility. Furthermore, a vast literature exists exploring these three areas and it is beyond the scope of this article to describe relative strengths and weaknesses of these. The three categories below are defined according to the common characteristic of each niche cluster, and include some key references for further details on each topic.

1. Radical vehicle technologies — increased proportion of renewable primary energy in the transport sector; through the development of biofuels[54], and through development of new energy carriers such as Hydrogen and Methanol[55,56]. Hybridisation and development of novel engine and drive train technologies[57], new functionalities linked to the continued development of an electric power train[58], and technologies providing overall greater energy-efficiency and new light weight solutions enabling more futuristic transport modes such as dual modes and Personal Rapid Transport Systems (PRT) [10]. These alternatives may be more or less ‘radical’ from the current regime, depending on the extent of new infrastructure, technological development and behaviour change required, and therefore more or less compatible with regime interests (see Fig. 2).

2. Product-to-service shift — cultural, institutional and behavioural changes support new modes of transport utilisation to enable more efficient use of resources and energy; through a product to service shift in the car industry focusing on mobility services provision and brands [37]; through car sharing and car pooling in both communal and commercial form [59–61]; and through an increased use of public transport.

3. Mobility management — this constitutes a more ‘local and green’ way of living with lower overall transport demand and resource consumption as a result of changes in values of quality of life and widespread institutional changes [39]. This niche includes: a positive development of slow-modes (walking and cycling) [62]; utilisation of ICT replacing transport demand [63] and demand management polices such as congestion charging and road pricing.

This article will explore the actual development of these areas of innovation, and discuss the potential for development within and between these areas of innovation. Fig. 2 indicates the relative compatibility or commonality (vis a vis technologies, practices,
values and actors) of each area of innovation with the regime. We consider this first area of innovation to be in a partially symbiotic relationship with most automotive regime actors, but more often antagonistic to fossil fuel energy companies. The second area of innovation may be either symbiotic or competitive with regime, and niche the third area of innovation has predominantly antagonistic relationships with regime.

Although we discuss these areas of innovation separately in subsequent sections, we do not assume that any one area of innovation alone might be able to achieve the diverse criteria for sustainable mobility outlined above; rather, as we suggest later in the paper, each contributing in different ways to sustainable mobility criteria outlined earlier, and the most promising outcome is a composite arrangement of aspects from all three niches.

5.1. Development of innovation area 1 — radical technological change

As mentioned earlier, European policy-making tends to favour technological solutions for tackling transport problems. In particular, there is increasing policy support for biofuels indicated by the 2003 Biofuel Directive (which specifies a 2% target in 2005 and 5.75% in 2010) and hydrogen and FC technologies (longer-term), given substantial resources for research and demonstration (e.g., the European Hydrogen and Fuel Cell Technology Platform). This is despite the considerable technical, physical and infrastructural barriers to realising these technological transport alternatives.

In Sweden, political support for development of renewable fuels has a long tradition following the 1970s oil crisis, and later in the response to the climate change debate. Most recently, a Commission of Oil Independence reviewed concrete options on how to break the remaining oil dependence in the Swedish transport sector by 2020. Renewable fuels for transport are exempted from energy and carbon dioxide tax applicable to fossil fuels; several Committees has addressed biofuels, and since October 2006 a component in car tax is also directly linked to carbon emissions per kilometre complementing the already existing carbon taxation of fossil fuels. A range of other incentives originating in policies directed toward carbon dioxide abatement also supports the adoption of alternative technologies (see Table 4). Both biofuels and Hybrid Electric Vehicles (HEV) are actively supported and benefit from lower taxes and local support schemes.

In the UK, alternative transport fuels and vehicle technologies — primarily biofuels, but also hydrogen and FCs and HEVs — are supported through a number of measures, including the establishment of the LowCVP stakeholder group to stimulate alternative vehicle technology development, and the hydrogen FC and HEV bus demonstration projects in London. In response to the EU Biofuels Directive, the UK has recently introduced measures to encourage biofuel uptake. Other schemes include energy labelling on new vehicles, introduced in 2004 (in advance of EU proposals to introduce such a scheme) (see Table 4).

As European car manufacturers have improved vehicle technologies, in line with voluntary EU agreements, vehicles sold in both Sweden and the UK have much lower proportions of local air pollutants than historically. Recent figures show a dip in UK sales of 4-wheel-drive vehicles/SUVs for the first time in several years. Availability of low-emission vehicles is also greater in the UK than in Sweden, and diesel vehicles are much more popular in the UK (26.7% of licensed vehicles) than in Sweden (9%) or other European countries, although the market share is rapidly increasing in Sweden with diesel having a 60% share of sales in 2007.

The market in Sweden for alternative fuels and propulsion technologies was until 2000 well below 0.1% in total. However, this situation is now changing. HEVs alone account for 0.2% in 2007 and the share is growing fast with a 1% market share in 2007. After a slow start, initial indications of stronger sales of fuel efficient vehicles also emerged during 2007 (see Fig. 3). In terms of

---

3 It should be emphasised that not all niche activities within this areas of innovation are symbiotic with the current regime. Most synergies are evident when new solutions can be bridged by hybridisations such as the HEV, or Flexi fuel concepts, and fewer or no synergies exist with aspects of more radically new propulsion systems. Nevertheless, we consider important aspects of this area of innovation to be in symbiotic relationship with the regime; furthermore, much (but not all) research and development on even the more radical solutions is conducted by actors currently within the regime.

4 Where no specific references are given in this section, figures come from the range of national sources previously cited in Methodology.
Table 5
Models with novel technologies in Swedish [104] and UK market [24,25], October 2006

<table>
<thead>
<tr>
<th></th>
<th>Sweden</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexi-fuel using ethanol and/or petrol</td>
<td>6 (+11 variants)</td>
<td>2</td>
</tr>
<tr>
<td>Diesel models certified for biodiesel</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Bi-fuel using CNG/biogas, and/or petrol</td>
<td>8 (+3 variants)</td>
<td>2</td>
</tr>
<tr>
<td>LPG</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>HEVs</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>BEVs</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

alternative fuels, Sweden has had a long period of what could be characterised as niche experimentation, innovation, and development preceding a potential biofuels transition. Sandén and Jonasson [69] review this development describing the important collaborations among public transport actors, car manufacturing companies, refilling station owners and municipalities. As of October 2006, a range of biofuel models is available and the number has been growing rapidly in the last six years (see Table 5) and sales of cars with alternative fuels or propulsion systems reached 12% in 2007. The largest quantity of biofuels is however used for blending in ordinary petrol and diesel. In 2005, over 90% of petrol sold in Sweden included the maximum 5% allowed level blending of ethanol, a very rapid growth since the practice started in 2002 [70]. For diesel, the corresponding trend has just started, and in 2005 10.5% of the diesel sold included the 5% allowed blending of biodiesel.

Uptake in the UK of alternative propulsion systems, including BEV and HEV, accounts for only 0.06% of all licensed vehicles in 2006. Alternative transport fuels, including liquefied petroleum gas (LPG), compressed natural gas (CNG), and biofuels, are somewhat more popular: LPG vehicles account for 0.09% of licensed vehicles, and CNG vehicles for 0.07% [71]. Uptake of biofuel vehicles has not yet reached levels of Germany (the highest in the EU) or Sweden; in 2004, biofuels accounted for only 0.06% share of the total transport fuels markets in the UK [71]. In Fig. 3 the most recently published figures from 2006 are shown. Most of this was domestic low-level biodiesel production from waste vegetable oil. However, Bomb and colleagues [71] argue this proportion is likely to increase as the biofuels industry becomes more organised and influential. The UK market is characterised by technology push, with actors driving this potential transition including the UK government, biofuels producers (e.g., farmers) and suppliers, and vehicle manufactures (notably Ford UK); while the public is not playing a significant role [71] Oil companies are more supportive of biodiesel (extending the diesel market) than bioethanol (reducing the petrol market); however, virtually all bioethanol is currently imported predominantly from Brazil rather than domestically produced, as is the case in Sweden.

In summary, we note promising developments within this area of innovation. However, the development is dependent on political support and momentum that could easily be withdrawn. There are severe limitations to the potential of biofuels (both in efficiency, supply, ecological sustainability of production, and not the least, competition with food at the global level), and the automotive industry is only reluctantly discussing binding targets for production of more fuel-efficient cars. Hydrogen fuel cell vehicles or electric vehicles following the plug-in version of hybrids seem to remain a widely favoured long-term strategy.

5.2. Development of area of innovation 2 — shift from products to services

In this section we investigate two aspects of a product to service shift. Firstly, modal shift in a traditional sense: from car to public transport. Secondly, we investigate indicators of a growth of alternative forms of car access and use. Modal shift away from personal car use to less polluting forms of transport has received some support within European transport policy-making in recent decades [19]. With Sweden being much more scarcely populated and with fewer and smaller metropolitan areas compared to the UK, debate has naturally centred on accessibility, safety and road quality rather than congestion and capacity. The Stockholm region, however, does suffer from bottlenecks in both rail and road infrastructure and regional policy making on infrastructure investments has been politically contested for several decades [72]. In recent years congestion and environmental concerns have led to a trial of congestion charges during the first half year of 2006 in Stockholm [73]. A revised system has been adopted in 2007. It is also interesting to note that a recent committee of inquiry for the first time reviewed options for establishing more sustainable consumption and production patterns including within the transport sector, highlighting PRT as an option to review further [74].

In the UK, there has been a shift in focus during the last 15 year s away from the traditional ‘predict and provide’ approach – building and expanding large-scale infrastructure in response to rising traffic levels – towards integrated demand management strategies and more local determination of transport policy [50]. This is reflected in recent legislation such as the Road Traffic Reduction Acts of 1997 and 1998 and the 2000 Transport Act (see Table 6). Years of under-investment in transport infrastructure, particularly the rail network, and rising public transport costs for users has contributed to major overcrowding on much of the rail network, and the most congested roads in Europe [75]. Growing international attention to sustainable development goals, increasingly militant anti-road protests and public spending cut-backs at national level [49], not to mention evidence that creating transport network capacity may in fact be counter-productive and stimulate additional demand [63], has contributed to a reduced focus on road building within UK transport policy and more support for activities within this second area of innovations. Following the success of the London Congestion Charge (which has led to a 30% reduction in congestion since 2003 [76]), the Transport Act of 2000 enables congestion charging and similar road pricing or workplace levy schemes to be introduced by other local authorities, in order to generate revenue for other transport-related projects. The Transport Act and 10-Year Plan [77] also provides for
improved rail and bus services (see Table 6). ‘Softer’ measures – including individualised marketing, travel-plans, and car-sharing – to encourage modal shift have also become popular in central government, not least because they do not involve major investment in infrastructure [63].

Car ownership is growing more rapidly in the UK than in Sweden, but is around the same level, with almost one car per 2 residents [16]. Also, the number of households owning two or more vehicles has increased significantly: in the UK this has risen from 13% in 1980 to over one-quarter of households by 2003 [18]. Car use in passenger kilometres as a proportion of total transport demand in Sweden (83%) is slightly lower than the average for EU-25, whereas the UK has a higher proportion (88%). Consistent with this, public transport use in the UK is lower than in Sweden (6% of travel in passenger kilometres accounted for by bus and 6% by train, compared to 9% and 8% in Sweden respectively).

In summary, studying car ownership and usage at the aggregate level, the trend is toward higher car dependence with no substantial increase in public transport. However, as we now discuss, some trends towards alternative forms of transport services are worth investigating.

A recent Swedish example of product-to-service shift is shown by Toyota, who initially introduced their new car Aygo solely as a subscription leasing service, marketing the car towards young consumers with urban lifestyles. The Aygo has low carbon dioxide emissions; 109 g CO2/km [78] – considerably lower than the average European car which emits 162 g CO2/km, and almost half the level of 197 g CO2/km in Sweden [79] (2006 official statistics, not deducting for share of biofuels cars). The introduction of the Aygo concept has been a commercial success according to Toyota Sweden [80] with double the estimated sales and an established 25% market share of the sub-compact segment during 2006. Around 60% of the sales featured this subscription service and it is now probable that Toyota will expand the concept to other modes and market segments. Traditional car leasing for both business and personal transport is widespread in Sweden and is increasing slowly, from 4.3% in 1996, to 5.9% in 2005 [81], with similar increases in infrastructure [63]. Finally, rental cars in Sweden also show a recent increase although a trend is difficult to estimate [84]. It is, however, difficult to estimate the importance of fuel efficient cars being marketed in this form, a single car maker or other actor promoting fuel efficient cars will have a limited impact and the market for fuel efficient cars is in Sweden has yet to take off. Should the trend of changing business model continue; this development has potential. Today, however, this has yet to be realised.

Another indicator that could highlight a shift away from car ownership is car sharing and car clubs. Such schemes indeed show rapid expansion in Sweden. Recent developments have established a range of transport service alternatives: ranging from ordinary full-service car rental to car sharing organisations with a high level of individual commitment for the shared car. Roughly 45 communal car sharing schemes with 1500 members exist [85], and two commercial car pools with over 3500 users [86,87]. Both types showed only some 500 members each five years ago and were only experimental some 10 years ago. The UK has also seen a gradual increase in the establishment of car share schemes and car clubs in the past 5–10 years, although levels in Sweden and UK have not yet reached those of Germany and Switzerland. A recent Department for Transport study [51] found some 480 reported UK-based ‘closed’ (i.e. organisation-based, local, or regional) car share schemes, over 40 ‘open’ schemes, and 29 reported UK based commercial car club schemes (of which 26 were active). Currently, there are 11,000 members in UK, but this is expected to rise to 160,000 [88]. In summary car sharing and car clubs are growing more than car ownership and has not yet reached it full potential. Crucially, however, the absolute numbers of individuals participating in these schemes are still very low. Hence, although this is an interesting development in both the studies countries, the rapid growth is easily achieved since the phenomenon is new in both Sweden and the UK and starts from a marginal level. The development cannot be interpreted as a substantial shift from ownership to services, and it is so far impossible to estimate the overall impact on car ownership from these trends.

Furthermore, should the shift from product to service, from traditional ownership to other forms of car access, be a real trend it cannot be viewed as a sign of a weakening regime per se. As discussed above, it is very difficult to estimate any actual demand reduction due to these trends. More interesting is that novel technologies are more rapidly taken up within transport services, and more efficient cars utilised when cars are bought as a service compared with ownership [59]. For example, an estimated 15–20% of rental cars are HEVs or alternative fuel cars in Sweden (26% in the Stockholm region), the two largest taxi companies in Stockholm
have 10–15% HEVs or alternative fuel cars [89], and one of the two commercial car sharing schemes uses only cars labelled environmentally friendly. The goal of the Taxi sector is in Sweden is a 60% share of alternative cars in 2010 [84]. A ‘green’ taxi company has recently opened in London: fleet cars are HEVs and all emissions are offset, while it claims that fares are no higher than other taxi firms [90]. Previous research highlights that taxi fleets and public transport fleet experiments create initial infrastructure build-up [69].

In summary, there is little evidence of a change in modal split to favour public modes; or a slow in growth of car ownership in either Sweden or UK. However, there is growth in car leasing and sharing. Further, there is evidence that fleet cars act as incubators for experimentation with new technologies and as early adopters.

5.3. Development of innovation area 3 – mobility management

Examples of policy instruments for transport demand management include congestion charging and road tolls, vehicle and fuel taxation, energy labelling of vehicles, and information campaigns/marketing. While there is indications of the success of such economic and informational measures (e.g., [76]), there are greater policy challenges associated with tackling the socio-cultural determinants of demand [41]. The policy context provides some support for this third area of innovation, but to date there has been little success in decoupling transport demand from income within Europe [49]. While demand for transport increases proportionally with income, there is statistical evidence that reduced income does not necessarily result in reduced demand for transport [91]. This is likely to be because individuals become used to, and (socially) dependent on, a certain standard of living and largely unconstrained personal mobility, and are therefore ‘locked in’ to this lifestyle [92]. Without bottom-up change in social values and transport policies that produce structural change (including infrastructural interventions like ‘home zones’, public transport and cycle paths) there may be a backlash against policies that restrict personal mobility, as demonstrated, for example, by the UK 2000 fuel duty protests.

Transport demand is, however, increasing across all modes, including private car as shown above. Average kilometres travelled per person per day is 36 in both the UK and Sweden, slightly higher than the EU-25 average [16]. Levels of walking and cycling (‘slow modes’) show a slight increase in Sweden, whereas they have decreased in the UK by almost 20% since 1990 to amongst the lowest proportions in Europe. This is despite targets to increase them as part of the 10-year transport plan [77].

While transport use is apparently stably locked into car use, there are some activities and early development associated with this third innovation area that should be scrutinised. Applications for new driver licenses are declining amongst the youngest age groups in both Sweden and the UK (Fig. 4). In Sweden, the trend could be partly explained by reduced levels of income in young age categories [93]; while in the UK, the Department for Transport [18] suggest this trend may be because the driving test has become more difficult, and/or due to increased costs of driving lessons and vehicle insurance. Overall there is an increase in the total number of driving licenses in the UK (from 64% of adults in 1991 to 70% in 2004), and a stabilisation (at 76%) in Sweden. In other words, people are so far merely delaying obtaining a driving license, rather than avoiding obtaining one altogether. Nevertheless, it is interesting to speculate about whether there is an emergent cultural shift away from the ‘car-culture’. Reduced share of young people attaining driving licences may still highlight an emerging trend for urban lifestyles, observed in Scandinavian countries. When the issue was studied by a Committee of Inquiry in Sweden [93] they concluded that the values attached to cars were significantly different among the young, and that they had a very pragmatic relationship to car use – as something merely supplying a transportation demand – particularly in larger cities with highly developed public transport. However, the report concluded that the potential for actual long term reduction of car dependence is dependant on young people to keep there values and remain frequent users of other modes of transport, and that public transport must remain attractive as income grows with age. Thus, unless these developments are paired with investments in public transport, a significant change is unlikely.

![Fig. 4. Driving licenses in Sweden and the UK, by age group.](image-url)
ICT development continues to fundamentally reorganise our communication patterns, and the resulting direct impact of home-working and internet shopping on road transportation is difficult to estimate; few figures directly link ICT development and transport demand. A recent review of the environmental impacts of the environmental impacts of ICTs suggests home-working can reduce transport demand for commuting, but may increase leisure travel (thus potentially neutralising the benefits of these technologies). The authors also review studies that suggest Geographical Information Systems for route planning could help optimise fuel usage [94]. Home shopping may also reduce overall transport demand [17].

Our analysis of national data suggests these technologies are increasingly being adopted. Home-working is statistically reported to be at a stable level between 4–7% in Sweden according to national statistics; while the use of video and telecommunications equipment is increasing with roughly 10% of all companies having access to video conferencing equipment [95,96]. The UK government estimates that 8% of the workforce work from home or use their home as a base for work; this proportion has doubled since 1997 [97]. The Institute of Employment Studies estimates that 22.6% of the workforce could potentially telework, the highest in Europe (cited in [98]).

ICT for home-shopping has increased rapidly in the UK and Sweden as the proportion of households with internet access at home has risen significantly in recent years. In 2005 in Sweden: 36% of the population and 66% of companies reported use of internet for purchasing goods or services. UK government figures for March 2002 [97] show that, of the 46% of adults who had accessed the internet during the past month, 38% ordered tickets, goods or services or searched for information related to education (a higher proportion browsed for information on services or goods). In February 2004, this figure had risen to 47% and in February 2005 it rose again to 56% [97].

In summary, polices such as congestion charging constitute a clear sign of a shift towards actively managing demand, but these early schemes have only a very limited local influence, with no significant impact on overall demand. And although there are strong trends in ICT use, which are reorganising consumption patterns, we have not identified any clear signs of this behavioural change actually replacing transport demand.

6. Analysis and discussion

In this paper, we have argued that the serious and persistent problems in the current mobility system suggest a need for a ‘transition’ – radical systemic change – towards sustainable mobility. While ‘sustainable mobility’ is a term that encompasses competing interests and values, we have adopted a broad definition which aims to contribute to social and economic welfare, without damaging the environment or depleting environmental resources. Thus, we have identified three broad areas of innovation containing a range of niches; the development of these areas of innovation may lead us towards a more sustainable mobility future in Europe by redressing the current imbalance which favours economic growth to the detriment of environmental or social well-being. This paper has examined qualitative and quantitative indications of the development of these areas of innovation and niche activities within two European countries: UK and Sweden.

A summary of this innovation development is given in Table 7. It should be emphasised that this method of analysing the trends only gives a qualitative picture. Furthermore, indicators are not weighted, and a different set of indicators could give a different picture, particularly in relation to estimating the continued dominance of the regime relative to the areas innovation. Nevertheless, strong trends are visible in the first area of innovation (transport technologies) and a take-off in alternative technologies most closely aligned with the regime (HEV, low-emission cars, and biofuel vehicles) can be observed, at least in Sweden. Although the empirical data suggests a slower growth in the UK of alternative fuels and propulsion technologies, sales of low-emission vehicles are increasing. No diffusion of the more radical technological solutions of BEV and HFC can yet be observed. Development within the second area of innovation (product-to-service shift) is ambiguous in both countries, with growth in the car service market and changes in age of attaining driving licenses, but a continued dominance of private car use. Finally, within the third innovation area (mobility management), there are interesting trends in both the UK and Sweden, including some policy support, growth of ICT for shopping and working, but no growth in use of slow modes or other evidence of a shift to a radically different behaviour.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Regime</th>
<th>Innovation area 1</th>
<th>Innovation area 2</th>
<th>Innovation area 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport demand</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>–</td>
</tr>
<tr>
<td>Social attitudes to transport and environment</td>
<td>?</td>
<td>+</td>
<td>?</td>
<td>–</td>
</tr>
<tr>
<td>Environment-related automotive R&amp;D</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>0</td>
</tr>
<tr>
<td>CO2 emissions from transport</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>Transport policy</td>
<td>?</td>
<td>+</td>
<td>+</td>
<td>?</td>
</tr>
<tr>
<td>Sales of alternative fuel/propulsion system vehicles</td>
<td>–</td>
<td>+</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>Sales of low-emission ICE vehicles</td>
<td>+</td>
<td>–</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>Car ownership</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Public transport use</td>
<td>0</td>
<td>0</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Car leasing &amp; sharing</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Uptake of driving licenses</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>ICT adoption</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>+</td>
</tr>
</tbody>
</table>
Sustainability is still relatively peripheral to transport regime interests, but is beginning to receive attention by both policymakers and firms. Together, the gradual institutionalisation of radical technology development and increased interest in sustainability within the policy context indicate that technological and policy dimensions of the regime are responding to landscape pressures on the system. Other dimensions, such as culture (e.g., cars as status symbols) and infrastructure are responding more slowly.

In addition, indications of niche interactions and accumulation cross the areas studied — such as transport service providers acting as incubators for new solutions and congestion charging being linked to new technologies encouraging changing consumer behaviours, as well as misaligned interests and tensions amongst regime actors in response to landscape pressures, together may be seen as the transport regime to some (limited) extent ‘opening up’ in response to the landscape changes. As mentioned, other regime dimensions appear to be more resistant to change.

We believe that discussions of pathways to sustainable mobility benefit from transition concepts such as niche and regime because they highlight important relationships between societal actors, learning and technology diffusion between niches and sectors, and emerging trends which contribute to innovation and future development. Consistent with historical studies of transitions (e.g.,[13]), we have found that the current mobility regime appears to be subject to internal tensions and is showing signs of ‘opening up’ in certain areas, with actor interests becoming misaligned and several regime groups exploiting niche innovations in an attempt to respond to landscape pressures. Cooperation between regime and niche actors is in some cases mutually beneficial: the niche offers potential solutions to regime and landscape problems, yet the regime has the resources to mobilise these solutions.

We have also found some heterogeneity within areas of innovation. Although we have highlighted various linkages between our three areas, we have also found that actors within each area of innovation do not necessarily have the same interests or compatible activities. This divergence is illustrated in that, for the different countries analysed, different technological niches are emerging as initially favoured solutions within the first area of innovation (biofuels in Sweden, and smaller fuel efficient cars in the UK). In innovation areas 2 and 3 in particular, our empirical evidence highlighted several diverging trends (e.g. high increase in car sharing, but overall increase in car ownership) which indicates these alternative solutions are unlikely (yet) to offer a coherent or stable alternative to the incumbent regime. This finding may indicate a weakness in our definitions of the innovation areas (and that alternative boundaries should be drawn around the innovations discussed), or that these groups will constitute a more stable and inter-dependent networks over time. Indeed, since the regime may be more or less aligned or stable over time, instability or inconsistency within the three areas need not undermine the validity of our analytical framework. Rather, the coherence and power of these areas of innovations and associated niche activities could be increased by explicitly developing sustainable mobility ‘visions’ with stakeholders and coordinating activities to achieve these visions [15]. This is crucial because neither technological solutions nor policy can reform transport alone. Indeed, attempts to introduce innovations for sustainable transport without the support of consumers and producers risk back-lash (e.g., fuel duty protests in the UK in 2000), and a short sighted technological fix evidently offers solutions to some problems only, and includes the very real risk of new solutions such as Ethanol becoming a new unsustainable lock-in as discussed earlier in the article.

What have we found to be the determinants, or necessary conditions, for emergence and growth of sustainable mobility in all our three areas of innovation? Firstly, they are determined by landscape pressures – both environmental (e.g., climate change), economic (e.g., oil prices, automotive and ICT markets) and cultural (value/behaviour change) – which in turn impact on policies at national and European level. At the niche level, there is interest in exploiting opportunities arising from these trends (for example amongst agricultural and emerging biofuel industries). Networks are beginning to emerge in some areas (e.g., biofuels), where supported by a favourable policy system. Regime actors are also beginning to respond to landscape pressures, and exploit technological opportunities and new markets (e.g., biofuels, HEV, and small fuel efficient cars). The regime is limited, however, in its capacity to respond to landscape pressures: for example, existing refuelling infrastructure and automotive expertise are not compatible with hydrogen transport technology development. Such barriers to a transition can be partly overcome through ‘hybridisation’. New hybrid solutions have both the existing standard and the advantages of new solutions (e.g. HEV and flexi-fuel solutions). Similarly, accumulation of concepts and solutions between the innovation areas opens up further radical development (e.g., product-to-service shift combined with new technologies); we also identify co-evolution between the innovation areas. Such processes play a key role in early niche formation [99].

Retaining the diversity of niche development (via incentives, fiscal measures, etc.) and avoiding new lock-ins is again confirmed as important by our study; and is consistent with the notion of Strategic Niche Management [14]. Notably, we would argue that the conditions in both Sweden and the UK for development within the first innovation area are now more favourable for a breakthrough than they were in 1998 when Kemp and colleagues analysed the transport sector in the Netherlands. Much of this can be attributed to the range of incremental policy responses within the regime in response to landscape changes. We want to highlight that policy solutions should be sought that achieve innovation of different kinds (new technologies, services, institutions), as well as relative sustainability in other sectors necessary for a sustainable mobility transition [3]. When congestion charging is accompanied by viable alternative transport modes, it has been shown to work: there are indications that congestion charging reduces congestion and fosters modal shift [76]. Its effectiveness in turn appears to have led to public acceptance in both London and Stockholm. Research has suggested that consumer behaviour is more sensitive to congestion charging and road tolls than to fuel taxes, which are not visible directly in the fuel price [100,101]. Further, alternative transport technologies are benefiting, since many are exempted from the charge. The recent sharp increase of alternative fuel cars that started in 2006 correlates with the period of congestion charges in Stockholm [101]. Since the Stockholm region in turn accounts for 40% of the alternative fuel cars sold in Sweden in 2006 the impact of the trials is far from negligible. This suggests congestion charging...
supports development in all three areas of innovations, and can offer benefits beyond merely congestion reduction and therefore is a good candidate of above discussed policies fostering sustainable mobility. However, results from Stockholm are only tentative based on a half year trial, and both cases in the UK and Sweden are only geographically limited schemes which means that further trials and research are needed.

This paper has assessed developments in sustainable transport within two European countries: the UK and Sweden. Future work should assess such developments within a broader range of European countries, to compare the influence of more diverse economic, social, geographical and political factors.

Acknowledgements

Several people kindly provided comments on previous versions of this article. We particularly thank Åsa Gerger Swartling, Jill Jäger, Paul Weaver, and two anonymous reviewers. The authors gratefully acknowledge financial and other support by the European Commission funded project MATISSE. Special thanks to our colleagues in work package nine: Alex Haxeltine, Jonathan Köhler, Michel Schilpoeord, and Noam Bergman, for intellectual support throughout the work.

References

researching carbon literacy, carbon offsetting and low-carbon lifestyles. She is a Visiting Fellow in the Psychology Department at the University of Bath.

She focuses on questions such as: How is sustainability treated in impact assessment procedures in the science-policy interface in Sweden? And what is the relationship between formal assessment tools and procedures, and institutional constraints limiting the decision-making processes? Ongoing research also aims at understanding transitions between different socio-technical regimes, and explores the role of social learning.

Dr. Lorraine Whitmarsh is a Senior Research Associate at the UK Tyndall Centre for Climate Change Research in the School of Environmental Sciences at the University of East Anglia. She completed her PhD, a study of public understanding of and response to climate change in the South of England, in 2005 at the University of Bath. Since joining the Tyndall Centre, she has worked on the EU-funded MATISSE project researching processes of innovation and behaviour change towards sustainability and developing participatory methods and modelling tools to support sustainability policy-making. She is currently researching carbon literacy, carbon offsetting and low-carbon lifestyles. She is a visiting fellow in the Psychology Department at the University of Bath.