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Identifying opportunities and pathways for transitions to sustainable transport in Sweden and the UK

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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., European Commission, 2001a; European Environment Agency, 2006). In respect of climate change, for example, transport is the sector with the highest increase of greenhouse gas emissions in recent decades, rising by 24% between 1990 and 2003 (European Environment Agency, 2005).

Given these problems, and their associated economic, social and environmental impacts, we can conclude that the current transport system is in many respects unsustainable. The concept of 'sustainability' is inherently subjective and contested; discussion and decision-making about sustainable futures therefore demands a more participatory and inclusive approach than traditional scientific models of knowledge production or policy assessment (Gibbons et al., 1994; Gibson, Hassan, Holtz, Tansey, & Whitelaw, 2005). Consequently, we have drawn on sustainable transport criteria expressed by policy-makers and other stakeholders (e.g., European Commission, 2001a; Whitmarsh & Wietschel, 2006) to identify opportunities and propose several *pathways* of developments towards a more sustainable transport future in Europe. We discuss how these pathways have emerged and examine to what extent they have developed - and might continue to develop - in two contrasting European countries (Sweden and the UK). Finally, we highlight the importance of co-evolution among the discussed pathways of developments supporting both near term changes as well as being the vehicle enabling more radically different transport solutions.

Section 2 describes the theoretical concepts (e.g., transition, regime, niche, niche-accumulation) we use to frame our research into sustainable transport. Section 3 outlines the methodology we have used to collect evidence of emerging 'transitions' to sustainable transport in two European jurisdictions: Sweden and the UK. In Section 4, we propose and describe three main pathways - vehicle technology, product-to-service shift, and post-industrial lifestyles - through which sustainable transport might be achieved. Subsequently, in Section 5, we review evidence for emergence and development of these pathways within Europe, particularly focussing on Sweden and the UK. In section 6 we discuss the possibilities for these pathways to co-evolve and finally, Section 7 discusses the implications of this evidence for future transport, and outlines plans for further research in this area.

2 Theoretical background

Explaining potential sustainable pathways for road based transport, is at its bottom line a study of transportation utilisation, primary energy sources, and vehicle technologies. Utilisation of transport includes a range of modes of transport, as well as the actual demand. Primary energy needs to be converted to an energy carrier and finally converted to mobile power. Different combinations of technologies for these conversions are more or less sustainable due to both the choice of primary energy and the efficiency of the technologies involved. Several promising technological options exist but to date no alternative can be described as the unquestionable winner for the future as concluded in a range of studies comparing different technological options (Ahman, 2001; Johansson & Ahman, 2002; MacLean & Lave, 2003; Hekkert, Hendriks, & al, 2005). It is in fact unlikely that there is a theoretically best option weighting all aspects of sustainable development together since conditions vary geographically, and future technological innovation is inherently difficult to foresee. Furthermore, tackling *all* aspects of sustainable transport will require both major technological and behavioural changes - and behavioural/cultural change will be at least as challenging as technological change. To date, policy measures to influence individual travel decisions (e.g., congestion charging, vehicle taxation) have had little effect relative to the underlying growth in demand. In some cases, interventions to reduce demand or foster modal shift have had the reverse effect (e.g., Goodwin et al., 2004). Similarly, 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 (European Commission, 2001b).

To this end, we argue that incremental technological or policy improvement is unlikely to be sufficient to address this type of persistent problem. Rather, we consider radical, systemic innovation - a ‘transition’ (e.g., Rotmans, Kemp, & van Asselt, 2001; Smith, Stirling, & Berkhout, 2005) - is necessary to move away from the current land-based transport regime and towards a more sustainable transport system. The literature on transitions highlights the interdependency of institutions and infrastructures constituting societal systems and sub-systems, which has created various types of lock-in that stifle innovation (Geels, 2005b). The dominant transport paradigm constitutes a regime locked in to a stable state of oil- and car- dependence (personal mobility, using internal combustion and steel chassis technologies) with infrastructure, manufacturing, and consumer behaviours enforcing the regime. In relation to infrastructure, the built environment has co-evolved alongside automobility, so that amenities and workplaces are often only accessible by car. Vehicle manufacturing has developed along ‘technological trajectories’ (Dosi, 1984), which constrains the development of vehicle and fuel technologies to the development of core competences, particularly in internal combustion engine and Budd-type steel chassis (Nieuwenhuis & Wells, 1997). Consumer decisions fulfil emotional-symbolic functions (e.g., status, comfort, safety) as well as practical requirements (space, cost, etc.) (Steg, Vlek, & Slotegraaf, 2001). Socio-cultural norms - for example, the expectation that quality of life entails vehicle ownership - and habitual behaviour serve to lock in these preferences and patterns of behaviour (Bandura, 1971; Verplanken, Aarts, van Knippenberg, & Moonen, 1998; Urry, 1999), presenting a major challenge for tackling unsustainable actions. Due to these psychological, technological and institutional dependencies, there is typically widespread resistance to radical change (Elzen, 2005).

Transitions theorists have developed the multi-level perspective (MLP) as an analytical frame for the empirical study of transitions. 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 (Geels & Schot, 2005; cf. Giddens, 1984). The *regime* comprises dominant actors, institutions, practices and shared assumptions (Rotmans, 2005). While it provides stability and cohesion of societal systems, it also tends towards incremental change and optimising the current system, using the capabilities and resources of dominant players. System innovation, or radical change, is restricted since habits, existing competencies, past investment, regulation, prevailing norms, worldviews and so on, act to lock in patterns of behaviour and result in path dependencies for technological and social development (Geels & Schot, 2005).

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 (although recent work suggests there are exceptions to this, in which regime capabilities are effectively transformed in response to landscape pressures: de Haan & Rotmans, 2006; Geels & Schot, 2005). 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. In the case of the current transport regime, for example, we can say it is misaligned with environmental, social and economic landscape conditions, as evidenced by the problems outlined in Section 1.

The niche and regime may exist in either a symbiotic or competitive relationship; furthermore, niche development of innovations may precede or follow landscape pressure on the regime. In response to landscape pressures, regime actors may also draw on niche expertise/innovations if they are unable to adequately respond with their own resources (Smith et al., 2005). As we discuss in the following sections, for example, several niche innovations (e.g., hydrogen fuel cell and hybrid vehicles) are funded and driven by regime actors (e.g., automotive industry) who perceive these as viable solutions to current landscape threats of resource depletion, climate change and industry regulation. 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. Bio-ethanol vehicle development, for example, is opposed by many fossil fuel companies; measures to reduce transport demand are resisted by many regime actors.

Central, then, to understanding many types of socio-technological transition is niche development (Geels, 2005b). This includes ‘niche-accumulation’, ‘technological add-on’, and ‘hybridisation’. *Niche-accumulation* refers to the gradual addition of a series of niche innovations and developments that facilitate the shift from an incumbent to a new regime. *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 (Geels, 2005b). In this article we use niche-accumulation in the sense of broad socio-technological transition, not only technological transition, to explore pathways for sustainable development of road based transport.

This MLP is complemented by the multi-phase concept. Building on the s-shaped (sigmoid) diffusion curve (Rogers, 1995), four phases of a transition can be identified: ‘pre-development’, ‘take-off’, ‘acceleration’, and ‘stabilisation’ (Rotmans et al., 2001). In the *pre-development* stage, there is uncoordinated experimentation at the niche level but no visible change in the status quo. By the *take-off* stage, a coordinated network of niche actors forms and a dominant concept of the innovation they are developing emerges; the technology/idea is used in niche applications and rapidly improves. The *acceleration* phase occurs when there is a convergence of pressures on the regime, which allows the innovation to diffuse rapidly. As the niche enters the mainstream, it challenges the incumbent regime and the structure of the system visibly changes. Finally, in the *stabilisation* phase, the speed of change decreases and a new dynamic equilibrium is reached once the old regime is replaced.

In this article we draw on the concepts outlined above to explore the potential for a transition to sustainable transport in Europe today. In particular, we identify three promising areas of niche development - vehicle technologies, products-to-services shift, and lifestyle change - which may contribute to the sustainable development of land transport. These are discussed in Section 4.

3 Methodology

This paper draws on secondary data and documentary analyses to explore various transport sector indicators and policies within Europe, particularly focussing on two member states: the UK and Sweden. These two countries represent diverse spatial, cultural and political contexts in which to explore the development and uptake of potential ‘sustainable’ transport niches. The UK has a much higher and denser population - and transport network - that Sweden: UK population is around 60 million, while Sweden has a population of around 9 million; yet citizens in both countries travel around the same distance on average each day (30km) (Strelow, 2006). Politically and culturally, Sweden has embraced sustainability more forcefully than the UK. While UK transport policies have prioritised tackling congestion, Sweden has a long history of niche experiments with alternatives fuels (Sandén & Jonasson, 2005), and a range of recent polices supporting introduction of renewable energy in the transport sector.

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 (primarily, Department for Transport, 2005b; Swedish Institute for Transport and Communications Analysis, 2006a). Vehicle sales data was obtained from European Automobile Manufacturers Association (http://www.acea.be) and national sources. Complementing short personal communications with experts were in a few cases conducted to obtain data on aspects of diche development 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 Opportunities for sustainable transport

4.1 Defining innovations for sustainable transport

In this section we draw on the concepts outlined in Section 2 to explore the potential for a transition to sustainable transport in Europe today. Firstly, we discuss the pressures and changes evident within the incumbent land-transport regime, including regime responses to landscape pressures (e.g., climate change). Secondly, we identify three promising areas of niche development, which may contribute to the sustainable development of land transport. These niches differ in their compatibility with the regime, with each positioned closer or further from the regime in terms of its technologies, practices, values and actors (see *Figure 1*).

i) *Novel vehicle technologies* – Increased proportion of renewable primary energy in the transport sector; development of novel technologies to use this energy; and technologies providing overall greater energy-efficiency [symbiotic relationships with most automotive regime actors, but more often antagonistic to fossil fuel energy companies]
ii) *Product to service shift* – Cultural, institutional and behavioural changes support new modes of transport utilisation to enable more efficient use of resources and energy [may be either symbiotic or competitive with regime]
iii) *Post-industrial lifestyles* – 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 [predominantly antagonistic relationships with regime]

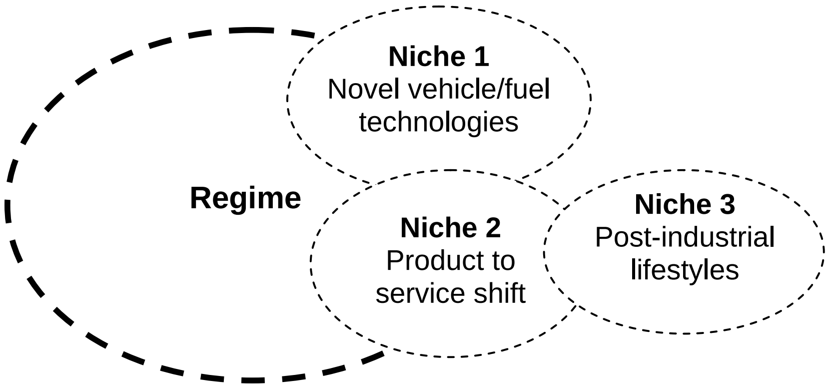


Figure 1. Indicative model of compatibility of regime and three identified niches. Primarily Niche 1, but also Niche 2 share many actors, activities and values with the regime; while Niche 3 constitutes a largely distinct set of actors, activities and values only shared with Niche 2. As will be discussed, Niches 1 and 2 also have some potential linkages through actors sharing values on new technologies such as fuel-efficient models or alternative fuels. The outlines of all three niches and the regime are broken because of the dynamic and heterogeneous constitution of niche/regime membership.

Each niche contributes in different ways to the criteria for sustainable transport proposed by various organisations and individuals (e.g., European Commission, 2001a; European Commission, 2006a; Whitmarsh & Wietschel, 2006; Commission Expert Group on Transport and Environment, 2000; SUMMA, 2005). Although different criteria are emphasised by different groups, broadly speaking sustainable transport 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' (World Business Council on Sustainable Development, 2004). The European Commission Expert Group on Transport and Environment (2000) defined a sustainable transport system as one that:

- "allows the basic access needs and development of individuals, companies and societies to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between generations;
- is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy, and regional development;
- limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and, uses non-renewable resources at or below the rates of development of renewable substitutes and minimises the use of land and the generation of noise".

Based on this definition, the SUMMA project has grouped the various dimensions of 'sustainable transport' under the three pillars of sustainability: social, economic and environmental (see Table 1).

Table 1. Dimensions of sustainable transport (SUMMA, 2005)

Economic outcomes	**Environmental outcomes**	**Social outcomes**
Accessibility	Resource use	Accessibility and affordability
Transport operation cost	Direct ecological intrusion	Safety and security
Productivity/ efficiency	Emissions to air	Fitness and health
Costs to economy	Emissions to soil and water	Liveability and amenity
Benefits to economy	Noise	Equity
	Waste	Social cohesion
		Working conditions in transport sector

There are three broad approaches to tackling unsustainable transport and achieving the criteria outlined above:

i) *Improving efficiency and reducing the impact of vehicles* (through improvements to existing vehicle technologies, development of new vehicle or fuel technologies, or change of driving technique, i.e., 'eco-driving')
ii) *Using more sustainable modes of travel* (increased use of public transport and slow modes).
iii) *Reducing the need to travel* (through lifestyle change and increased use of ICT)

Each of the three niches 1 to 3 discussed in this paper employs at least the corresponding approach above, but more then one are addressed in some. Finally, although we discuss these niches separately in subsequent sections, we do not assume that any one niche alone might be able to achieve the diverse criteria for sustainable transport outlined above; rather, as we suggest later in the paper, the most promising outcome is a composite arrangement of aspects from all three niches.

4.2 Sustainable transport at the regime level

During the past two decades, there has been a significant cultural shift within the automotive and energy industries, as in wider society, towards recognition of landscape pressures, including climate change, air pollution and resource depletion. This change has perhaps been most evident amongst US automotive firms. Hoffman (2001) describes the 1970s and 80s as a time when 'any talk of advanced propulsion technologies, clean energy, or concern with environmental issues was considered heresy in the blinkered automotive world of Detroit' (p.102). Since then, all major car firms have begun investing in more environmentally-benign vehicle and fuel technologies, including catalytic converters, three-way catalysts, and more recently hybrids, biofuels, hydrogen and fuel cells (Köhler, Whitmarsh, Michie, & Oughton, 2007).

The policy regime began to respond to rising air pollution threats to health in urban areas in 1960 in California and in 1970 across the US with the passing of the federal Clean Air Act (Gerard & Lave, 2005). More recently, climate change, congestion, life cycles/resource use and 'liveability' for citizens have become the focus of policy attention (Elzen, 2005; Nieuwenhuis & Wells, 1997). Although EU transport policy has historically focussed on liberalisation and harmonisation of transport to form a single trans-European transport network (European Commission, 2001a), more recently it has incorporated sustainability considerations into transport policies. Mobility is one of the six priority areas of the EU's Sustainable Development Strategy (European Commission, 2001b). Furthermore, the European Commission's (2001a) *White Paper on the Future Common Transport Policy* highlights a range of initiatives necessary for tackling problems of sustainability in the transport sector, including fostering modal shift towards environmentally friendly modes (rail, inland waterways, short sea shipping); promoting alternative vehicle and fuel technologies; improving efficiency; and internalising environmental costs in transport prices. Together with the industry responses to economic and environmental landscape pressures, these policy shifts suggest an 'opening up' of the prevailing regime to consider more (radical) sustainable transport systems.

However, a closer look at the transport regime highlights that this is not a homogeneous group of actors; in some cases, interests have become misaligned in response to landscape pressures. An example is the response of the natural gas and oil industries to biofuel development, lobbying the UK government to impose standards in order to constrain and delay commercialisation (Taylor, 2006). Transport policy responses similarly indicate competing priorities and ambiguity, with more attention currently given to economic (e.g., costs of congestion and infrastructure) and environmental impacts (emissions) of transport than social impacts, such as exclusion and community severance (see also Section 5.1.2). In Sweden on the other hand, the biofuels lobby has successfully influenced the regime in the past ten years, visible through the active policy making of the former Swedish government (A new centre right coalition is in place as of

September 2006), and the gas and oil industries are adapting and increasingly supplying alternative fuels. While the regime is adapting in some aspects, new issues are emerging such as conflicting interest over incentives for domestic production of biofuels vs. cheaper imports, debate over the potential loss of ecosystem services due to intensified land use, and lock-in to new inefficient technologies. These examples of tensions are what de Haan and Rotmans (2006) refer to as 'stress' - internal misalignment within the regime - which is typically a precursor to transition; notably in the case of the transition from horse-drawn carriages to automobiles the old regime collapsed completely before a new regime emerged (Geels, 2005b).

Within wider society, too, there is considerable resistance to changing behaviour to more sustainable forms. Driving is not only the most convenient and often the cheapest form of transport it is also tied to social values and identity (e.g., Steg et al., 2001). In the UK, for example, there is a widespread association between car ownership and 'having a good lifestyle' (Whitmarsh, 2005; cf. Black, Collins, & Snell, 2001). MORI conclude that most people in the UK are 'determined to retain car use in the face of virtually any barrier - excessive cost, tighter legislation, vehicles banned from urban centres etc.' (Norton & Leaman, 2004, p.9). This is despite public recognition of the need to tackle rising congestion and other transport problems (Department for Transport, 2005a). In the case of Sweden, Nilsson and Küller (2000) find similar patterns in the literature describing values attached to cars in Sweden (p 213), and show that car affection and ownership have a negative influence on pro-environmental awareness and behaviour. It has also been shown that public acceptance of road pricing among car owners in Sweden decreases if it is perceived as unfair or limiting freedom (Jakobsson, Fujii, & Garling, 2000). Interpreting freedom resulting from this car ownership as an attribute of having a good lifestyle MORI's conclusion is supported also in Swedish culture of car ownership.

4.3 Niche 1 - Radical technological change

All major car manufacturers are investing in alternative vehicle and fuel technologies. Radical technologies, especially hydrogen and fuel cells, were initially developed by 'niche' players or outsiders (e.g., universities, firms in other sectors or enthusiastic amateurs, entrepreneurs or start-ups), but have now been 'institutionalised' into mainstream auto firms (van den Hoed & Vergragt, 2004). This institutionalisation of radical technology development can be described as a regime response to landscape changes. Increasing oil prices and awareness of scarcity of oil supplies, growing societal recognition of environmental impacts such as climate change and local air pollution from transport are examples of landscape changes forcing the regime to open up. The solutions, or rather adaptations, closest aligned with the regime are technological fixes. There is also a political preference for technological solutions to environmental/sustainability problems - the so-called 'techno-fix' or 'end-of-pipe' approach. These tend to offer economic as well as environmental benefits (win-win) (see European Technologies Action Plan: European Commission, 2002), and avoid the more challenging issue of changing consumer behaviour.

Novel vehicle technologies with regard to sustainable transport can be divided into two main areas. First, technologies enabling use of different sources of primary energy including conversion to different energy carriers; and second, the chemically stored energy can be converted to mechanical energy for mobile power by different set of technologies or drive trains. Finally, development of technologies for efficiency gains such as lightweight chassis or increased

Internal Combustion Engine (ICE) efficiency are ongoing and to a large extent in symbiotic relationship within the regime. More radical radically efficiency gains as a consequence of this trend will be discussed in later sections.

Viable options for renewable primary energy are electricity from solar, hydro, tidal, wave, and wind energy, and biologically produced and chemically stored energy in carbon hydrates. These technologies exist, but are not all economically viable, and there is a multitude of technological options being developed in parallel. There is a rather large variability between car manufacturing companies in terms of focus of R&D in new technological solution, but also in terms of level of ambition and strategy. Virtually all invest in different novel technologies (Köhler et al., 2007) heading for future developments, but some are leading in commercialisation of new solutions.

Each set of technologies under development will not be reviewed in detail here, but some basic features will be discussed. Energy carriers directly linked with the types of primary energy are electricity stored in batteries (or directly supplied from grid) and different liquid or gaseous biofuels. A wide range of options for the later category of biofuels exist among which Ethanol, Methane, and Bio diesel are the most developed and spread today, see Table 2. Reviews of these different options include Johansson & Ahman (2002), MacLean & Lave, (2003), Sandén & Jonasson, (2005), and Semelsberger, (2006), Azar, Lindgren & al (2003). Hydrogen as an energy carrier can be produced with a range of technological options (Wietschel, 2006); in many aspects it is comparable to electricity as it is independent of primary energy source. Seemingly, Methanol is an energy carrier that can be produced from a range or sources with similar technologies as Hydrogen. Finally, technologies challenging the dominant technology of Internal Combustion Engine (ICE) in terms of drive train solutions are Fuel Cells (FC), batteries, and electric motors, and novel ways of combining these options as in Hybrid Electric Vehicles (HEV).

Table 2. First and second generation biofuels.

First generation biofuels – Fermented and reformed biomass	*Second generation biofuels - Gasified and synthesised biomass*
- Methane from renewable resources, often referred to as biogas - Ethanol - Fatty Acid Methyl Esters (FAME), often referred to as bio diesel.	- Gaseous: Fischer Tropsch Diesel (FTD) - Liquid: Methanol, Dimethyl Ether (DME)

However, sustainable transport pathways do not exclude fossil alternatives in the short to medium term. Renewable primary energy could be introduced gradually, with more efficiently used fossil primary energy in the short- to medium-term (Hekkert et al., 2005; Wietschel, Hasenauer, & al, 2006). It is also likely that a widespread use of carbon sequestration from continued fossil fuel use is needed in order to meet the global energy demand under CO2 emission constraints Widening the definition of sustainability, from energy for transport only, and studying the global energy system with stringent carbon dioxide emissions, it can be argued that it is better to continue the dependence of fossil oil based fuel use in transportation, and focus renewable energy to power and heat sectors (Azar, Lindgren, & al, 2003)..

There is an extensive amount of literature discussing the comparative advantages of different combinations of fuels and power train technologies (Johansson & Ahman, 2002; Azar et al., 2003; MacLean & Lave, 2003; Hammerschlag & Mazza, 2005; Romm, 2006) often also broadening the discussion to include primary energy supply for energy carriers (hydrogen and electricity), since the sustainability of each combination is evidently determined by the well-to-wheel analysis (Semelsberger, Borup, & al, 2006; Wietschel et al., 2006).

However, while HEV technologies are being discussed as one of the most promising pathways with a rapidly developing market in the wake of the success of Toyota's Prius, few have discussed the importance of hybridisation and technological add-on in the context of wider niche-accumulation, enabling transition pathways. Johansson and Ahman (2002) and Romm (2006) discuss hybrids as a technological solution with different fuels, comparing its potential to other alternatives. Yet others do not agree that hybrid solutions as such offer a cost effective solution (Lave & MacLean, 2002).

Sandén and Jonasson, (2005) are inspired by the transition frameworks of Geels (2002; Geels, 2005a) and Rotmans et al. (2001) in their discussion of bio-fuel development in Sweden with the help of the concepts of landscape, regime, niches and niche-accumulation, but fail to broaden the discussion to hybrid technologies and technological add-on. Several authors also argue for the potential for other combinations of technologies. The most prominent are: 'plug-in hybrids' (the intermediate of a BEV and a HEV) (Romm, 2006), and hybrid FC-electric cars (Jeong & Oh, 2002; Pede, Iacobazzi, & al, 2004). Hekkert and others (2005) review options for Natural Gas (NG) use and discuss two different transition pathways to a sustainable transport future based on NG. However, this analysis does not include Ethanol and Biogas, and fails to broaden the discussion to the hybrid drive train potential.

Merging the different strands of literature on novel vehicles technologies for road-based transport, we conclude that all of these solutions might have a role and could be included in a transitions framework. Different technological solutions have their pros and cons, with no solution the obvious winner (cf. Köhler et al., 2007). Hydrogen and FCs offer potentially very clean, efficient and quiet technologies, but their rate of development and cost recitation is highly uncertain (McDowall & Eames, 2006). Furthermore, a sustainable hydrogen path fundamentally requires rapid development of renewable energy for electricity production being the primary energy supply. First generations of bio-fuels are already becoming consumer cost-effective and available within European markets, but current options do not offer an efficient carbon dioxide emission reduction path compared to use of biomass in power heat generation, and the bio resource base is limited imposing severe constraints on future bio-fuel supply. The different versions of HEV offer efficiency gains and new compelling opportunities to bridge current technologies to future high efficiency pathways and BEV solutions, but are so far rather expensive.

In addition to the weaknesses of each of the niches, outlined in Table 3, novel vehicle/fuel technologies are unable to contribute to social aspects of sustainable transportation, such as accessibility, obesity and congestion (Whitmarsh & Wietschel, 2006). Furthermore, OECD research (see CST, 2001) indicates that technology alone would only be able to offer 41% of the necessary reductions to mitigate climate change; the remainder would need to come from changes in transport demand and use. On the other hand, development of these technologies presents economic opportunities for the automotive and related sectors, and is compatible with regime values of ‘automobility’, and final choice of climate change mitigation strategies must be assessed cross sectors.

Table 3. Strengths and weaknesses of Niche 1 developments

Categories of Niche development	**Strength**	**Weakness**
HEV	High potential to become new standard Uses existing infrastructure	Fossil-fuel dependent
BEV and plug-in hybrids	Flexibility of primary energy sources, enabling shift to renewables	Battery technology immature, with high cost and practical constraints Need for (some) new infrastructure
Biofuels	Low CO2 emissions Economic opportunities for other sectors, e.g., agriculture	Land (area) constraints – competition with food Risk of unsustainable use of land Need for (some) new infrastructure
Hydrogen and Fuel cells	Enables use of broad range of renewable primary energy in transport No emissions at point of use Reduced vehicle noise	Immature technologies – high uncertainties over range of aspects, including the sustainability of the primary energy Need for new infrastructure

4.4 Niche 2 - Shift from products to services

This niche encompasses a shift from product to service provision by automotive firms, as well as transport service provision by public transport (bus, train, etc.) companies. Town planning policies and initiatives to support shared and collective forms of transport and to discourage private car use (e.g., bus lanes, car-share parking zones) are also associated with this niche. Landscape changes affecting this shift are mainly related to continued urbanisation. Urban lifestyles are less dependent on individual transport, and more closely aligned with ICT than with car ownership. Growing problems with congestion and commuting times as well as local air pollution contribute to the broader development of Niche 2.

Some firms (notably, GM and Toyota) are not only developing new competences in vehicle technologies in response to environmental change, but are also changing their business model away from vehicle production and towards provision of services such as vehicle rental, servicing and finance. Seidel and colleagues (Seidel, Loch, & Chahil, 2005) identify the possibility that the large-scale car makers will continue to move in this direction towards a ‘brand worlds’ scenario involving a shift to mobility service provision and an expansion into other consumer products.

A shift from car ownership to car transport service acquisition also extends beyond the automotive industry. Car-sharing schemes have so far played a minor role in societies in both the UK and Sweden and the topic is relatively little discussed in literature (see Enoch & Taylor, 2006 for a recent review). Throughout Europe there are some 120,000 members of car sharing schemes (Enoch & Taylor, 2006) and the potential of car sharing in Europe has been discussed by Prettenthaler & Steininger (1999) and then estimated to roughly 9% of present car owners through a survey in Austria, a figure affirmed by a Swedish car sharing expert Peter Markusson (Markusson, 2006) in the case of Sweden. This figure is however not an upper limit, but estimations given the present regime, that is including ‘lifestyle characteristics’ and current behaviour patterns. Mont (Mont, 2004) discusses car sharing in the wider context of a product to service shifts and also recognises two different Car Sharing Organisations (CSO); Communal and Commercial (Mont, 2004, p. 141). The development of information technology solutions are important drivers in this niche as explored by Shaheen (Shaheen, 1999, p. 4). Easy-to-use web-based booking, electronic keys, GPS- and GSM-based tracking of driving distances, and automated invoicing are some examples of developments that reduce the cost of such systems and make them easier to use (Swedish road administration, 2002).

A range of very fuel efficient ICE cars such as the Toyota Aygo, Citroen C1, and Peugeot 107 demonstrates that transport needs can be met with less fuel consuming cars. With transportation marketed as a service the price is likely to be relatively more important than the performance and prestige of owning a higher end car which in turn puts pressure on lower fuel consumption. Comparing i) privately owned, ii) shared cars, and iii) rented cars, Prettenthaler and Steininger (Prettenthaler & Steininger, 1999, p. 449) show that there are significant differences in engine size between the three types ordered as the above list.

Finally, the growth of this niche contains modal split, and continued development of alternative transport services. Growth of purchased car services in this niche could contribute to the development of public transport since access to alternative means of transport when car services are not bought is necessary (Prettenthaler & Steininger, 1999), but we also include endogenous growth of public transport services and solutions.

Although great variability in public transport infrastructure investment and use exist within the current broad transport paradigm, there is considerable room for growth of the public transport sector. Light rail and trams virtually disappeared throughout the 20th century as cars became the dominating mode of transport (Geels, 2005b), but face renewed interest once again in Sweden and elsewhere throughout Europe due to landscape developments, discussed above. In the longer run, further developed public transport is a forerunner to advanced, individualised public transport solutions such as Personal Rapid Transport (PRT) (Caroline J. Rodier, 1998). Already, several metro systems globally operate autonomously. ICT development in general also contributes to efficient public fleet management and consumer information, making public transport more cost effective and reliable.

The contribution of this Niche to a more sustainable transport system is through more efficient resource use and reduced congestion due to lower levels of absolute number cars in society, and relatively high energy efficiency. A growing service sector could be a key driver to both increased use of public transport and more radical energy efficiency innovations in terms of the ICE engine, light weight materials and eventually wider use of hybrid electric technologies. Alternative car services and car sharing also offers social inclusion since this form of car use is cheaper than private ownership, and in wider terms communal CSO fosters sustainability oriented (community) world views.

Table 4. Strengths and weaknesses of Niche 2 developments

Categories of Niche development	**Strength**	**Weakness**
Car manufacturer switch from product to service	Efficiency Technology driver Regime actors leading	May still rely on fossil fuels
Car sharing and rental	Resource efficiency Social inclusion (reduced costs, community interaction) Compatible with existing 'automobility' values	Some problems with accessibility and availability – Mainly limited to urban areas with broad growth potential and alternative modes
Public transport	Resource efficiency Social inclusion (reduced costs, community interaction)	Can suffer from poor public perceptions (status, safety, comfort) Problematic for mobility impaired or transporting luggage

4.5 Niche 3 - Post-industrial lifestyles

This niche is the most radical of the three - representing the most divergent cultures and practices from the current regime, and therefore predominantly comprising alternative institutions and actors. In essence, this niche represents reduced travel demand. This encompasses walking and cycling ('slow modes'), and use of ICT for home-working and -shopping, as well as methods of town planning and development that encourage reduced travel demand (e.g., cycle lanes). Common to the activities that comprise this niche is a less consumer-oriented (individualistic) and more sustainability-focussed (community) worldview. The car has lost its unique symbolic status and is regarded simply as another 'white good' (e.g., refrigerators, washing machines) (Nieuwenhuis & Wells, 1997); autonomous personal mobility is less important than convenient, safe, affordable, and clean transport. In effect, this closely mirrors the *Local and Green* scenario developed for the East of England (Turnpenny, O'Riordan, & Haxeltine, 2005) or the *Local Stewardship* Foresight scenario developed for the UK Office of Science and Technology to inform policy-making in several government departments. These scenarios emphasise pro-sustainability cultural values and lifestyles focussed around local communities. This niche also has close links with the product-to-service niche (Niche 2), which - in contrast to the current regime - has little value attached to vehicle ownership.

This niche is likely to have the greatest potential for achieving a transport future that is sustainable in its broadest sense (encompassing social, as well as environmental and economic benefits). Firstly, with the most rapidly-growing proportion of greenhouse gas emissions coming from transport, reduced transport demand is a core element of climate change mitigation. There is also evidence that increased traffic reduces opportunities for social interaction, and can result in community severance (Appleyard, 1981). Therefore, reducing traffic flows through residential areas - for example, creating 'home zones' - can encourage community cohesion and improve road safety and environmental quality (Department for Transport, 2005a). Research into 'soft transport measures' (i.e., not involving major investment in infrastructure), such as travel planning, individualised marketing, car-sharing, and increased use of home-working and -shopping, suggests these can reduce transport demand by up to 21% in peak times (Cairns et al., 2004). However, other research suggests there may be rebound effects from increased use of ICT for home -shopping and -working, with transport demand being displaced into (and even increased in) other activities, such as leisure (Skinner, Fergusson, Kroeger, Kelly, & Bristow, 2004). This highlights the important intrinsic psychological and social values associated with transport held by many people (Ory & Mokhtarian, 2005).

In many respects, Niche 3 development is being fostered through landscape changes, as well as policy intervention on a number of levels. Landscape changes include changes in societal values beyond materialistic to post-materialistic values, and greater concern for quality of life and environmental quality than income. This is reflected, for example, in the development of European and member state sustainable development policies (e.g., Department for Environment Food and Rural Affairs, 2005) which give attention to community cohesion, quality of life, and environmental quality, along side economic indicators such as GDP. Furthermore, several studies suggest an emerging change in behaviours and attitudes to car ownership and use, in particular among young citizens, a growing proportion of whom in several European countries are choosing not to obtain a driving license (e.g., Cedersund & Henriksson, 2006; Department for Transport, 2005b). Kondratiev Wave theory predicts that the shift from cars to ICT as the dominant socio-technical systems 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 (Freeman & Louçã, 2001; Seidel et al., 2005). The automotive industry is very mature, characterised by fierce competition, fully-exploited economies of scale, and low profitability (Köhler et al., 2007); 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. Consistent with this theoretical framework, home-working and -shopping, and web-based communities, may ultimately replace the need for much travel.

The policy context is also largely favourable for development of this niche. Climate change and energy policies include measures for demand management (e.g., DEFRA, 2006). Furthermore, with congestion and social inclusion a concern for many European member states, national transport and related policies are increasingly supportive of these niche activities.

Examples of policy instruments include congestion charging and road tolls, vehicle and fuel taxation, energy labelling of vehicles, and information campaigns/marketing. However, while there is evidence of the success of many of these economic and informational measures (e.g., Transport for London, 2006), there is also a need to address the socio-cultural determinants of demand. Contrary to the predictions of post-materialist theory (Inglehart, 1990), to date there has been little success in decoupling transport demand from income within Europe (Glaister, 2002). Goodwin et al (2004) highlight asymmetry in the income-travel demand relationship - while demand for transport increases proportionally with income, reduced income does not necessarily result in reduced demand for transport. 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. The social and cultural dimensions of car ownership and use (e.g., Steg et al., 2001) pose a challenge for effective policy-making. 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, in the UK 2000 fuel duty protests.

Table 5. Strengths and weaknesses of Niche 3 developments

Categories of Niche development	Strength	Weakness
Slow modes (walking, cycling)	Health benefits Widely accessible (no/low cost, community interaction) Zero emissions/ low resource use	Limited range
ICT for home-shopping and -working	May improve work-life balance May reduce emissions and congestion	May lead to increased transport demand in other areas (e.g., leisure) Reduced community interaction Potential exploitation (e.g., low pay)

5 Evidence for pre-development and take-off phases of sustainable transport transitions in UK and Sweden

In the section we summarise the evidence of ongoing predevelopment of a transition to more sustainable transport within Sweden and the UK. For reference, and as evidence of active support for sustainable options in the transport sector throughout the three discussed niches, this section begins with a review of relevant polices in the two countries. Following that, we present evidence of market/technological and cultural/behavioural change that may indicate active development of Niches 1, 2, and 3. The evidence is presented separately for Sweden and UK, with aggregated discussion and conclusion in the final sub-section. The complex and interlinked future development in between these niches is not directly visibly in a single indicator. Instead, we present a wide range of indicators highlighting some key aspects of each niche and in the following section try to sketch ongoing and potential future niche-accumulation.

5.1 Policy context

Policies and assessment practice for sustainable development are still very much challenging the existing paradigm in Europe in general and Sweden in particular (Jordan et al., 2006). The prevailing paradigm of economic growth limits policies related to sustainability to those most closely aligned with Niche 1. Sustainable development is an increasingly prioritised issue at the level of rhetoric, as expressed at EU level in the Sustainable Development Strategy and Lisbon Agenda, and at national level in corresponding strategies addressing sustainability issues. In practice, however policies are largely sectoral and developed and assessed with a broad gap between best practice guidelines and reality (Jordan et al., 2006). Transport is no exception, and policies supporting sustainable transport are to be sought in sectoral approaches to addressing congestion, air quality, safety, new technologies, climate change etc. The following two sections give a descriptive jurisdictional background and highlight policies framing sustainable transport development.

5.1.1 Sweden

Recent Swedish policy making on transport increasingly embraces sustainable development as an aspiration (Regeringskansliet, 2006). Safety, social inclusion, accessibility, public transport development, and to some extent reduced environmental impacts of transport (green tax reforms from income to CO2), have been key aspects of transport polices by the Social Democrats influenced and supported by the green and left parties over the last 12 years (Swedish Road Administration, 2006b). However, Sweden is heavily dependant on the vehicle manufacturing industry with two car producers (Volvo and Saab) and two truck producers (Volvo and Scania) within a relatively small country, and the policy paradigm is in broad terms well-aligned with the current transport regime. This was illustrated only recently when the government acted swiftly when GM-owned car manufacturer Saab faced major potential job losses. Previous infrastructure budgets were altered, increasing investments beneficial to Saab/GM in the west cost region, and the threat of close down of production capacity was withdrawn by GM.

The most prominent policy issue on road based traffic in Sweden is probably safety. Aspects of safety are deeply embedded in the transport regime in Sweden, with the two car manufacturers Saab and Volvo being pioneers in safety innovation. Transport policies and adoption of safety measures are aligned with this regime and Sweden was an early adopter of legislation on seat belts and other safety measures. In 1995 a 'Vision Zero' was adopted with the goal of reducing fatal accidents to zero. The Swedish road administration work with several measures such as alternating 2+1 lane highway with a median barrier (a road type developed in Sweden), programs for alcohol ignition interlocks in duty vehicles, and an aggressive expansion of automated road safety cameras capturing violations of speed limits (Swedish Road Administration, 2006a) . Another recent legislation in this area is a law for children and adolescents up to the age of 15 to wear a cycle helmet when riding a bicycle.

Infrastructure investments in general have declined since a peak in 1960 and during the latest 10 years railroad infrastructure has been given increased relative priority over roads. With Sweden being much more scarcely populated and with fewer and smaller metropolitan areas compared to the UK, the debate is naturally centred on accessibility and road quality more so then capacity. However, in recent years congestion has been increasingly debated, linked to environmental concerns, and a trial of congestion charges was conducted during the first half year of 2006 in Stockholm. The Stockholm region suffers from bottle necks in both rail and road infrastructure and regional policy making on infrastructure investments have been politically contested for several decades.

Fossil fuels for road based vehicles are historically taxed with different ratios of Energy tax and Carbon dioxide tax depending on fuel type and use. These taxations are not enforced on renewable energy carriers with zero net CO2 emissions (Svensk Författningssamling, 1994). Also, starting in October 2006, there is a component in this tax directly linked to nominal CO2 emissions per kilometre for the vehicle.

Finally, it should be highlighted that a recent committee inquiry for the first time reviewed options for sustainable consumption and production in general (Statens Offentliga Utredningar, 2005b).. This report included several suggested measures on how to achieve a generic shift from resource intensive products to a service based economy among which a few have been implemented the last years.

Box 1. SWE transport and transport-relevant policy instruments

Generic transport policies:
Punctuality and Information, and Accessibility for disabled, have continuously been worked on in the current transport policy regime and are important aspects of the latest strategic bill from the government (Regeringskansliet, 2006)
Road safety: A 'Vision-Zero' of eliminating lethal accidents is in place since 1997 and has since become a guiding principle and prioritised area of work for the Swedish Road Administration (Swedish Road Administration, 2006a).

Congestion

- Test period of congestion charges in Stockholm during first half of 2006. Probable adoption of a reviewed system in 2007 (Svensk Författningssamling, 2004b)

Climate Change policy regime

- As of May 2006 taxation of private cars and other light duty vehicles is linked to carbon dioxide (CO_2) emissions (Svensk Författningssamling, 2006).
- A range of local initiatives within municipals creating incentives for individuals such as free parking and subsidised purchases, as well as support for filling stations to add a fuel pump for a renewable fuel. These initiatives originate from a generic investment program 'Klimp' supporting investments in abatement of CO_2 emissions through the Swedish Environmental Protection Agency (Svensk Författningssamling, 2003).
- Two recent pieces of legislation impose a requirement for agencies and authorities to buy or lease a minimum of 50% environmental friendly cars as of 2005, and 75% from 2006 (Svensk Författningssamling, 2004a, 2005a).
- Employees utilising a car supplied by his or her employer have to pay a tax corresponding to some of this added value. For cars using renewable fuels or with a hybrid technology, a tax reduction guarantees that this taxation is at the same level for such a car as for a comparable car with a petrol or diesel engine. The otherwise more expensive environmentally friendly car is hence subsidised in this context (Skatteverkets meddelanden, 2005; Svensk Författningssamling, 1999).

Alternative fuel infrastructure regulation.

- Requirement for gas filling stations to supply bio-fuels if above a certain size (Svensk Författningssamling, 2005b).

Product to service shift

- Recent committee reviewed measures for increased product to service shift in general with numerous suggestions for how to support such a transition (Statens Offentliga Utredningar, 2005b)

5.1.2 UK

"The British travel much the same as other Europeans, yet our road and rail network is the least developed of any major country - the result of decades of below average investment. As a consequence we have overcrowding on much of the rail network, and the most congested roads in Europe. Travel is forecast to continue to grow, and congestion will worsen further by 2010" (Strategy Unit, 2001).

Research into the development of transport policies in the UK indicates evidence of a shift in focus during the last 15 years. Transport planning has traditionally followed a 'predict and provide' approach - building and expanding large-scale infrastructure in response to rising traffic levels. In particular, since the Beeching reforms of the 1960s spending on road infrastructure has radically increased, while the rail network - including stations, tracks, rolling stock and staff - has been reduced, contributing to the major increases in road-based freight and personal transport. At the same time, the cost of motoring has remained relatively constant, while the cost of public transport has risen (ref). This is despite increases in fuel prices and fuel taxation: by 2000, UK petrol had become the most expensive in Europe (Glaister, 2002). During the 1980s and 1990s, the Conservative government privatised the railways, and bus companies outside of London, limiting governmental control over public transport. Current annual expenditure on road infrastructure is £5 billion [to add: rail].

With growing international attention to sustainable development goals, increasingly militant anti-road protests and public spending cut-backs at national level (Glaister, 2002), not to mention evidence that creating transport network capacity may in fact be counter-productive, stimulating additional demand (Cairns et al., 2004), transport policy in the UK is beginning to focus less on road building and more on integrated demand management strategies (Bulkeley & Rayner, 2003). This is reflected in the government's 1998 white paper *A New Deal for Transport: Better for Everyone* (Department of the Environment Transport and the Regions, 1998), which highlighted the need for more strategic and integrated transport planning including greater local authority control over public transport providers, and the Road Traffic Reduction Acts of 1997 and 1998.

The creation of the Greater London Authority through the GLA Act of 1999, which provided the Authority with powers to use revenue from user-charging, paved the way for the introduction of the London Congestion Charge. This scheme, which currently charges drivers £8 per day to enter central London (with reductions for residents and exemptions for buses, taxis and certain other vehicles including alternative-fuel vehicles), is widely regarded as successful: since its launch in 2003, there has been around a 30% reduction in congestion, as well as fewer accidents and emissions, with no negative impact on businesses in the capital. The revenue generated by the Charge (£122m) has been largely spent on improving bus services (Transport for London, 2006).

The subsequent 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. More recent policy discussion has focussed on standardising road pricing schemes by introduction of a national road pricing framework and road pricing pilots (Letter to PM, July 2006; DEFRA, 2006). The Transport Act has also seen the creation of the Strategic Rail Authority, with responsibility for increasing the capacity of the rail network. The UK's rail system is notoriously outmoded, and part of the government's *10-Year Plan* (Department for Transport, 2000) involves extending and modernising the rail network. Other improvements to public transport are also outlined in the Plan, including encouraging local authorities to procure bus services through Quality Contracts, and increased local authority spending on bus schemes, including bus lanes and the 'rural bus grants' and 'urban bus challenge'.

'Softer' measures to encourage modal shift and reduce transport demand have also become very popular in central government, not least because they do not involve major investment in infrastructure. Following research which suggested that soft measures - including individualised marketing, travel-plans, car-sharing and more tele-working/shopping - could cut urban traffic by 21% in peak periods (Cairns et al., 2004), the government has launched three Sustainable Travel Towns to pilot such measures and is encouraging schools to develop travel plans. Other schemes include energy labelling on new vehicles, introduced in 2004 (in advance of EU proposals to introduce such as scheme).

Alternative transport fuels and vehicle technologies - primarily bio-fuels, but also hydrogen and fuel cells and hybrid ICE-electric - are also supported through a number of measures. London has been the focus of both hydrogen fuel cell and hybrid bus demonstration projects. The government has also established the LowCVP stakeholder group to stimulate alternative vehicle technology development. In response to the EU 2003 Biofuels Directive, which specifies a 2 % target for 2005, the UK has recently introduced measures to encourage bio-fuel uptake (see Box 2).

Furthermore, the Labour government has reformed regional planning guidance and processes of appraisal, to promote more strategic, participatory and integrated transport planning at the local level (Bulkeley & Rayner, 2003). Shared priorities for local transport planning were agreed in 2002 by central government and the Local Government Association. These included: improving accessibility and public transport and reducing the problems of congestion, air pollution and safety.

Here, however, researchers have highlighted a 'potential tension between the existence of nationally declared objectives for transport policy and the discretion allowed for local determination' - through stakeholder involvement - of the strategic objectives that should inform Local Transport Plans (LTPs) (Bulkeley & Rayner, 2003). Furthermore, Wood et al (submitted) highlight the inconsistency in Guidance for the LTP development, stating both that the transport-related quality of life issues of climate change, sustainable communities, the quality of public spaces and landscapes, conservation of biodiversity, community safety, public health, and noise - are 'no less important than the shared priorities' but also need *not* be considered 'as key priorities'. Furthermore, other researchers point out that there is little evidence of decoupling GDP from transport demand, and a lack of genuine commitment to reducing demand for fear of alienating the 'motoring majority' (Glaister, 2002; Bulkeley & Rayner, 2003). In particular, there is a 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. Indeed, despite the change in political rhetoric and introduction of demand management initiatives, vehicle kilometres and associated greenhouse gas emissions in the UK are continuing to rise (Department for Environment Food and Rural Affairs, 2003).

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: Letter to PM, July 2006; DfT, 2004) rather than politically less popular measures to mitigate climate change and improve accessibility. Expanding road network capacity through programmes of road widening and building continues to be a core area of government transport policy (DfT, 2004) - albeit in combination with measures such as road tolls and carpooling (High Occupancy Vehicle) lanes - suggesting they have not yet fully rejected the traditional 'predict and provide' model of transport planning. Furthermore, the focus in the UK on tackling congestion seems to be to the detriment of climate change mitigation measures, since fuel duty may be reduced or removed in favour of differentiated 'pay-as-you-go' road pricing to discourage driving at peak-times [ref].

Box 2. UK transport and transport-relevant policy instruments

Graduated Vehicle Excise Duty and Company Car Tax
Since 2001 and 2002, respectively, these have been linked to vehicles' carbon emissions. The Budget in 2006, decreased to £0 the tax on the lowest emission vehicles to develop this market (company car tax fuel benefit charge was also reformed in 2003 to favour lower emission vehicles)

Renewable Transport Fuels Obligation
To be introduced in 2008 - five per cent of transport fuel sold in the UK will have to come from renewable sources by 2010. Budget 2006 announced that the level of obligation will be 2.5% in 2008-09 and 3.75% in 2009-10. This measure encourages clean production of biofuels through state aid awards, and encouraging sustainable sourcing of biofuels through a carbon and sustainability assurance scheme

Alternative Fuels Framework
Includes 20 pence per litre duty incentive for bioethanol and biodiesel until 2008-09

Hydrogen and Fuel Cells Demonstration Programme
This will provide £15m support from four years from 2006 to demonstrate hydrogen and fuel cells, including the use of hydrogen as a transport fuel

Alternative refuelling infrastructure grant programme.
This could, for example, include funding for hydrogen, electric, bio-ethanol and natural gas/biogas refuelling points: Details of the grant programme are at www.est.org.uk/fleet/funding/infrastructurep.

Powering Future Vehicles Strategy (2002)
Sets out the main policies and targets in this area and a grant programme supports research and development into low carbon vehicle technologies. (www.est.org.uk/fleet/funding/lowcarbonresearch/)

National Air Quality Strategy
Objectives for carbon monoxide, lead, nitrogen dioxide, particles, sulphur dioxide, benzene and 1, 2-butadiene (Joint DfT/Defra target)

Climate Change Programme (2006)
Includes:

- *Sustainable distribution scheme in Scotland,* which provides advice on reducing lorry mileage, fuel consumption and accidents;
- *'Smarter choices'* soft measures to encourage modal shift and reduce demand;
- *Sustainable Travel Towns* and six cycle demonstration towns;

- *Rural bus grants* and *urban bus challenge;*
- *Grants for rail freight* - currently around £20m each year;
- *Vehicle fuel efficiency labelling* introduced in 2005 to inform car buyers about the benefits of lower emissions vehicles;
- Funding for the *Low Carbon Vehicle Partnership* (LowCVP), a stakeholder organisation set up in 2003 to help the shift towards low carbon vehicles and fuels;
- Launch of *Transport Direct transport information service* - to help encourage a move to more environmentally friendly means of transport;
- *Carbon off-setting* of Presidency of EU and G8, and all of central government since April 2006;
- Use of *renewables and CHP by Highways Agency to power road network lights and communication.*

Local authority transport measures include congestion charging, bus lanes, parking measures, etc…

5.2 Technology and market development

Technologies such as catalysts and particulate filters lowering emissions from cars have evolved rapidly since emission standards for passenger cars and light vehicles were initiated in the EU in 1993. In this section we primarily review market development for alternative fuels or propulsion system technologies to counter fossil fuel use and thereby climate change. The picture of innovative technologies is somewhat mixed throughout Europe. Germany, which is the leader in biofuels use in Europe, has adopted bio diesel as the primary alternative fuel (Christian Bomb, Article in press), while Sweden is a leader in Ethanol and biogas use, and others are yet to initiate programs on bio fuels. Overall, the market is rapidly evolving.

5.2.1 Sweden

The Sweden petrol fuelled ICE cars have completely dominated road based personal transport historically. Diesel account for only 5% of light vehicles in 2005 but is increasing due to changed taxation levels relative to petrol. The market for alternative fuels was until 2000 well below 0,1% in total. However, this situation is now changing rapidly.

Sweden has had a long period of what could be characterised as predevelopment for a bio-fuels transition. Sandén and Jonasson (2005) make an excellent review of this development describing the important collaborations among public transport actors, car manufacturing companies, refilling station owners and municipalities. They describe 30 years of predevelopment where ideas on alternatives shifted from methanol, to methane, to ethanol, and how from this mixture of niche developments a range of pilot projects emerged. Finally, successful initial build up of ethanol and NG buses and related initial infrastructure development in conjunction with climate change debate entering the policy making context lead to decisions within Volvo to start producing CNG vehicles (for NG or Biogas) on a commercial basis in the late 1990s. Ford flexi fuel vehicles were at the same time imported starting in 1999 for commercial sale, and in 2004 the decision was taken among both Saab and Volvo to start producing E85 flexi fuel vehicles (Sandén and Jonasson, 2005).

Today (October, 2006) a range of models is available and the number is growing rapidly (see Table 6). Several renewable fuels are now gaining momentum and the estimated share of environmentally friendly vehicles sold (including hybrids) for 2006 is roughly 13% compared to 4% in 2005. The share of these alternative fuel technologies will be almost 2% of the total stock by the end of 2006.[1]

Table 6. Models with novel technologies in Swedish market

- ICE-electric hybrids (4 models - Honda Civic, Lexus GS450H and RX400H, Toyota Prius)
- Bi-fuel/flexi fuel using Ethanol and/or Petrol (17 models – 11 versions of Ford Foucs, 4 versions of Saab 9-5 , Volvo S40 and V50)
- Bi-fuel/flexi fuel using Natural gas and/or Petrol (11 models – Fiat Punto, Mercedec-Benz E200NTG, Opel ComboTour CNG, Volksvagen Golf Variat and Tuoran EcoFuel, Volvo S60, S80, V70 both manual and automatic transmission versions)
- Diesel models certified for RME (7 models from Seat - 2 versions of Cordoba, 3 versions of Ibiza, one Altea, and one Toledo)
- Fuel efficient, lower than 120g/km (6 models – Citroën C1 1,0, Peugeot 107 1,0, Toyota Aygo 1,0, Smart Fortwo 0,7, Kia Picanto 1,0 Citroën C3 1,6 HDi)

Source: The Swedish Consumer Agency

The largest quantity of bio-fuels 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 (Svenska Petroleuminstitutet, 2006). For diesel the corresponding trend has just started and in 2005 10.5% of the diesel sold included the 5% allowed blending of bio-diesel, or FAME. Hybrid models on the market have a small share in absolute terms, but 2004 and 2005 constituted a breakthrough with doubling of number cars in the total fleet (see

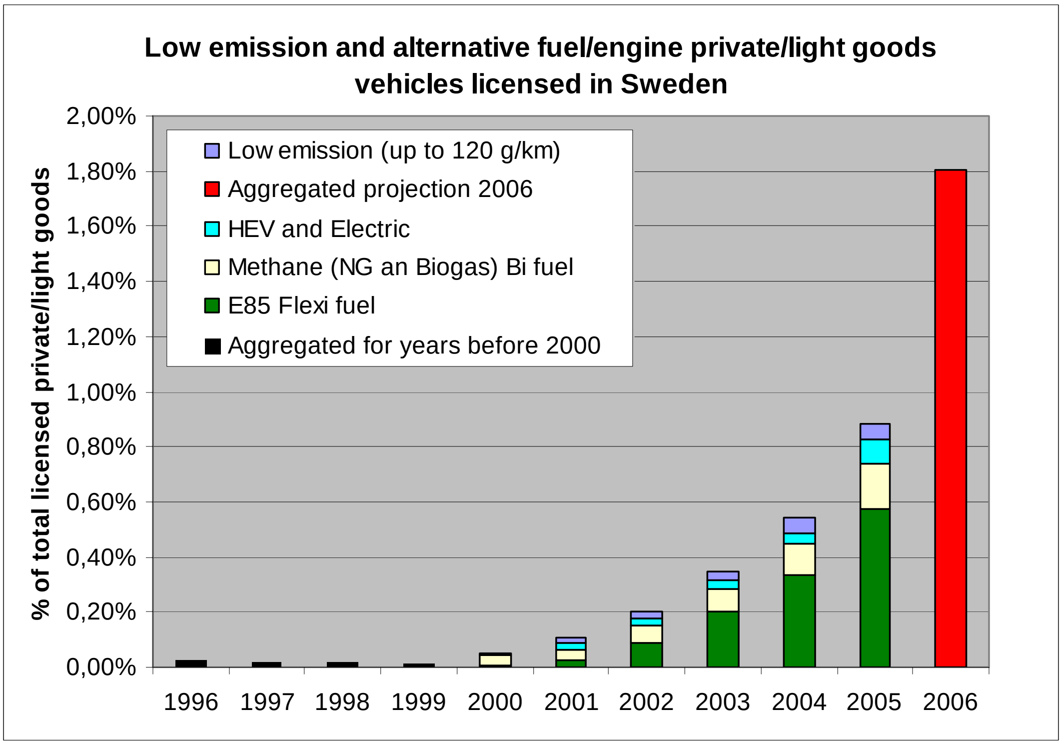
Figure *2*)

Studying the market development in
Figure 2 with the policy context presented in the previous section and predevelopment phase sketched above, the market for alternative fuels could be described as incentives coincided with decisions among car producers and retailers to put vehicles on commercial sale. Initial infrastructure is available due to build up in niches, and hybridisation of existing petrol and new alternative fuel technologies in “flexi”-fuel and “bi”-fuel solutions further ensures that consumers will not have to limit use to areas with filling stations supplying the alternative fuel. A steady growth of cars using alternative fuels was established between 2000 and 2004, accounting for a few percent of the total sales. During the later half of 2005 the sales increased further from an average 4% to roughly 13% during spring 2006. Interestingly this increase correlates with the period of congestion charges in Stockholm and the sales figure for the Stockholm region during

[1] These figures, and the following figures on environmental friendly cars are taken from the following sources unless otherwise stated: Bil Sweden (http://www.bilsweden.se), Swedish Association of Green Motorists (http://www.gronabilister.se), and Miljöfordon.se (www.miljofordon.se).

spring 2006 is 20% as reported by the body “Stockholmsförsöket” summarising the results of the test period.

Figure 2. Alternative fuels and technologies as share of total stock of cars in Sweden



In terms of novel technologies within transport services an estimated 15-20% of fleet cars for rent are hybrids or alternative fuel cars and the two largest taxi companies in Stockholm have between 10 and 15% hybrids or alternative fuel cars[2]. Fleet cars hence act not only as incubators for predevelopment, but also early adopters in the ongoing take-off phase. A recent Swedish example of product to service shift from Sweden is Toyota who initially introduced their new Aygo model solely as a leasing service, marketing the car towards young consumers with urban lifestyles. The Aygo is a very small car, powered with a 1.0 litre three-stroke engine with only 4.6 l fuel consumption per 100km according to the manufacturer. This corresponds to 109 g/km CO2 emissions, which is considerably lower than the average European car which emits 162 g/km CO2, and almost half the current level of 197 g/km in Sweden, in turn the highest figure in Europe (Toyota, 2006; European Commission, 2006b). Innovations like Aygo have an important potential contribution to sustainable transport in terms of reduced CO2 emission compared to the industry average. The recent introduction of Aygo has been a commercial success according to Toyota Sweden (Dahlström, 2006) with double the estimated sales and an established 25% market share of the sub-compact segment. The success of the subscription business model, specifically aimed at younger consumers with the ambition to create a predictable monthly low

[2] Newsletter from Miljöbilar i Stockholm • 3/2006

cost according to Dahlström, account for 60% of the sales. It is now probable that Toyota will expand the concept to other modes and market segments.

5.2.2 UK

Table 7. Models with novel technologies in UK market

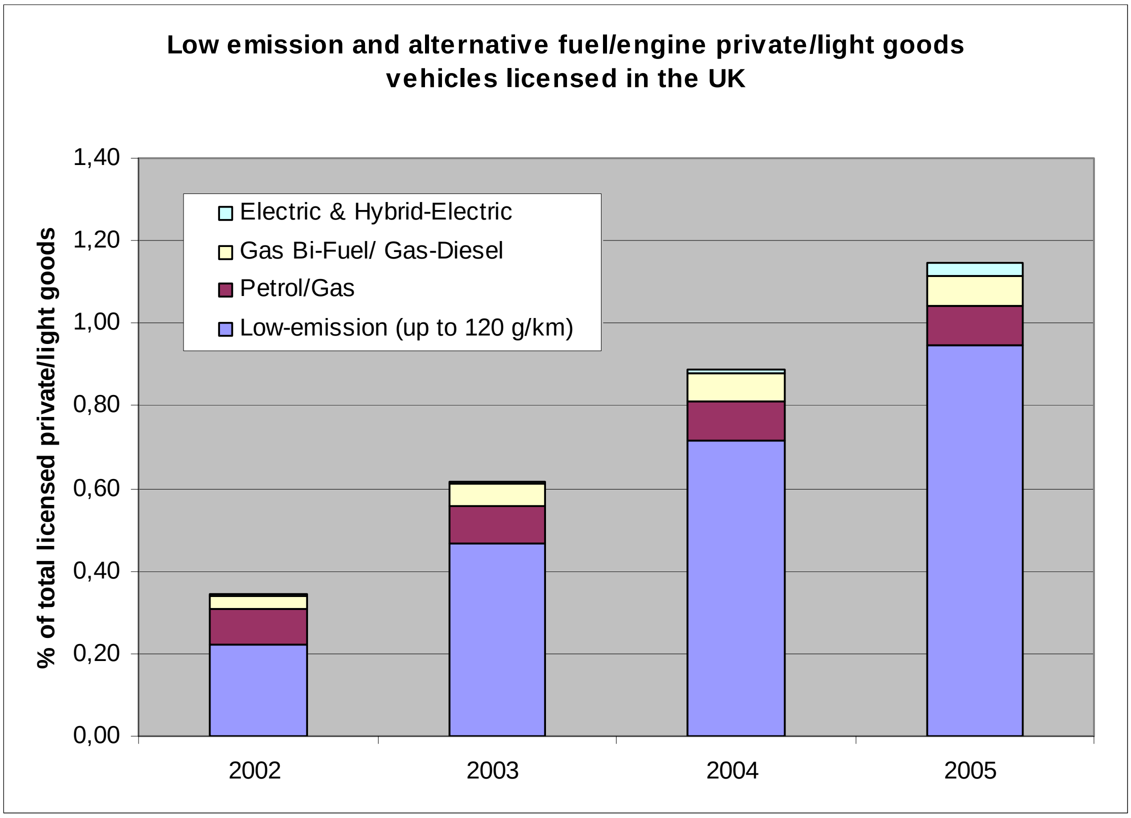
- ICE-electric hybrids (4 models - Honda Civic, Lexus GS450H and RX400H, Toyota Prius)
- Bi-fuel/flexi fuel using bio-ethanol and/or gasoline (2 models: Ford Focus flexi-fuel vehicle (FFV), Saab BioPower)
- Electric vehicles (2 models: GoinGreen G-Wizz, Peugeot 106 electric)
- Liquefied petroleum gas (LPG) (5 models: Vauxhall Astra, Vauxhall Vectra, Vauxhall Zafira, Volvo S/V40, Volvo V40)
- Compressed Natural Gas (CNG) (2 models: Volvo S60, Volvo S80)
- Bi-fuel/flexi fuel using Natural gas and/or Gasoline (none)
- Diesel (most models available in diesel)
- Fuel efficient, lower than 120g/km: (30 models: Toyota Prius, Honda Civic hybrid, Citroen C1 petrol, Citroen C1 diesel, Citroen C2, Citroen C3 manual/automatic, Toyota Aygo petrol, Toyota Aygo diesel, Peugeot 107, Smart Fortwo, Daihatsu Charade, Vauxhall Corsa petrol, Vauxhall Corsa diesel manual/automatic, Smart Roadster, Daihatsu Sirion, Fiat Panda, Ford Fiesta 1.6l/1.4l, Smart Forfour, Peugeot 206, Renault Clio, Hyundai Getz, Audi A2, Fiat Grande Punto, Ford Fusion 1.6l/1.4l, Toyota Yaris, Renault Modus)

Source: www.whatyoucando.co.uk/travel_switch; www.vcacarfueldata.org.uk

As European car manufacturers have improved vehicle technologies, in line with voluntary EU agreements, vehicles sold in 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 (Department for Transport, 2005b). Diesel vehicles are much more popular in the UK - accounting for around a quarter of all licensed vehicles (8.6m out of 32.2m) - than in other European countries (Eurostat, 2006; Department for Transport, 2005b). Petrol remains the most popular fuel, with 23m petrol vehicles currently licensed in the UK. Availability of low-emission vehicles is greater in the UK than in Sweden.

Uptake in the UK of alternative propulsion systems, including electric and hybrid electric, accounts for 14,900 (0.5%) of all licensed vehicles. Alternative transport fuels, including liquefied petroleum gas (LPG), compressed natural gas (CNG), and biofuels, are somewhat more popular: LPG vehicles account for 28,100 (0.9%) of licensed vehicles; CNG vehicles account for 22,900 (0.07%) (Bomb et al., 2006). Uptake of biofuel vehicles has not yet reached levels of Germany (the highest in the EU); in 2004, biofuels accounted for only 0.06% share of total transport fuels markets in the UK (Bomb et al., 2006); most of this was domestic low-level bio-diesel production from waste vegetable oil. However, this proportion is likely to increase with the introduction of policy incentives to stimulate biofuel markets, and the recent emergence of a bio-ethanol refuelling infrastructure in two regions of the UK. 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 (Taylor, 2006; Bomb et al., 2006). “There are signals that the biofuels industry is becoming more organised” in the UK; this emerging industry is “engaged in transforming the institutional infrastructure as well as the physical infrastructure” (Bomb et al., 2006, p.7-8). Oil companies are more supportive of bio-diesel (extending the diesel market) than bio-ethanol (reducing the petrol market); however, currently, all bio-ethanol is imported predominantly from Brazil rather than domestically produced.

Figure 3. Alternative fuels and technologies as share of total stock of cars in UK



5.3 *Cultural/behavioural context*

Overall, transport demand is rising across Europe: with the highest rises in Ireland and Portugal. While car use is typically increasing in EU-15 countries, new member states have typically lower proportions. Decoupling of transport demand and income has been achieved in few countries.

5.3.1 *Sweden*

In Sweden, transport demand is increasing across all modes, but primarily private car (*Figure 4*). Average kilometres travelled per person per day is 36, slightly higher than the EU-25 average (Strelow, 2006). However, Sweden's proportion of car use (83%) is slightly lower than average for EU-25. Bus and train use in Sweden accounts for 9% and 8% of travel, respectively. Finally, car ownership is growing in Sweden, with almost one car per 2 residents (Strelow, 2006). In summary, studying car ownership and usage at aggregate level, the trend is toward higher car dependence. However, applications for new driver licenses are declining amongst the youngest age groups (

Figure 5). This may highlight an emerging trend for urban lifestyles, observed in Scandinavian countries, which depend on slow and public transport modes (Nenseth, 2005).

Teleworking and Internet shopping
Support for a shift in consumer behaviour towards growth in Niches 2 and 3 can also be found in indicators of utilisation of ICT. ICT for home-shopping has increased rapidly both among individuals and firms: 36% of the population and 66% of companies reported use of internet for purchasing goods or services in 2005. The resulting direct impact on road transportation is difficult to estimate; few figures directly linking ICT development and transport demand can be found. Home working is statistically reported to be at a stable level between 4-7% according to national statistics[3] but the use of video and telecommunications equipment is increasing and roughly 10% of all companies have access to video conferencing equipment (Swedish Institute for Transport and Communications Analysis, 2000; SCB, 2005).

Car sharing and car clubs
A rapid expansion of car sharing can be observed in Sweden (Figure 6). Recent developments in Sweden have established a range of transport service alternatives: Ordinary full-service car rental, communal car sharing organisations (CSO) with a high level of individual commitment for the shared car, and commercial alternatives in between. In Figure 6 estimated total members in car sharing schemes with access to communal and commercial car pools are presented for a selection of years for which data could be obtained through personal communication and media (Markusson, 2006; Malmstörm, 2006; Edenhall, 2005).

Car Leasing and Rental cars
Finally, the trend for rental cars shows an increase in purchased and total number of cars within the sector, but a trend is difficult to estimate. More stable figures in terms of number of purchased services and total turnover in the sector indicate that the trend could be explained by a higher turnover of cars (BURF, 2006). Car leasing is relatively widespread in Sweden and is increasing slowly, from 4.3 percent in 1996, to 5.9% in 2005 (Swedish Institute for Transport and Communications Analysis, 2006b).

[3] www.scb.se

Figure 4a. Travel demand in Sweden, by mode

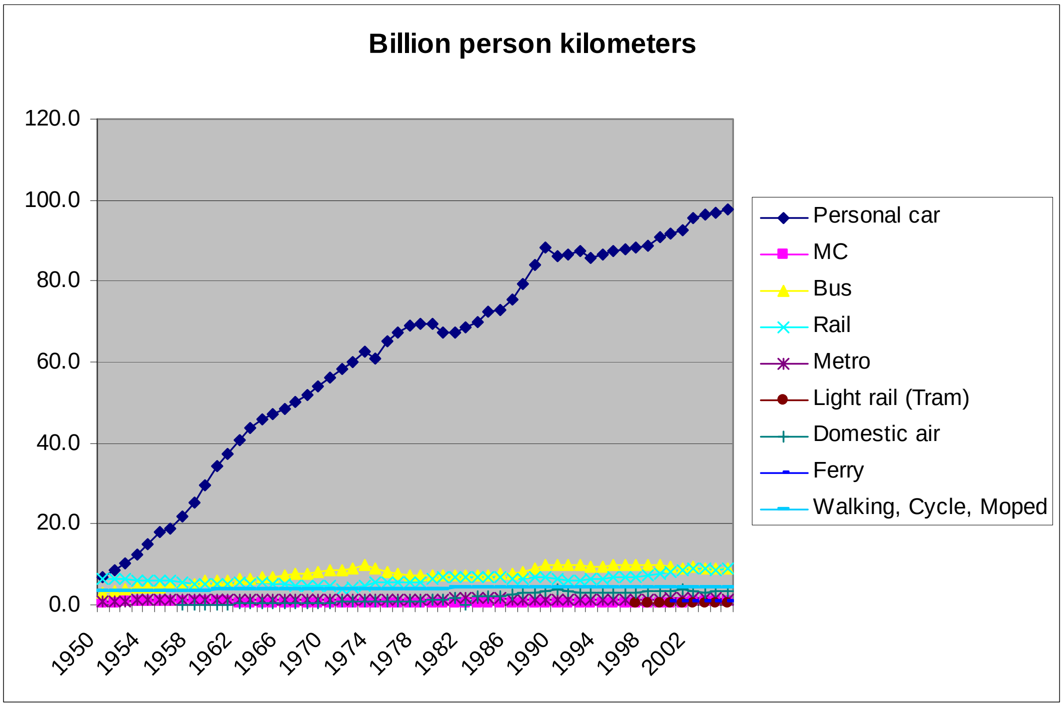


Figure 4b. Travel demand in Sweden, by mode

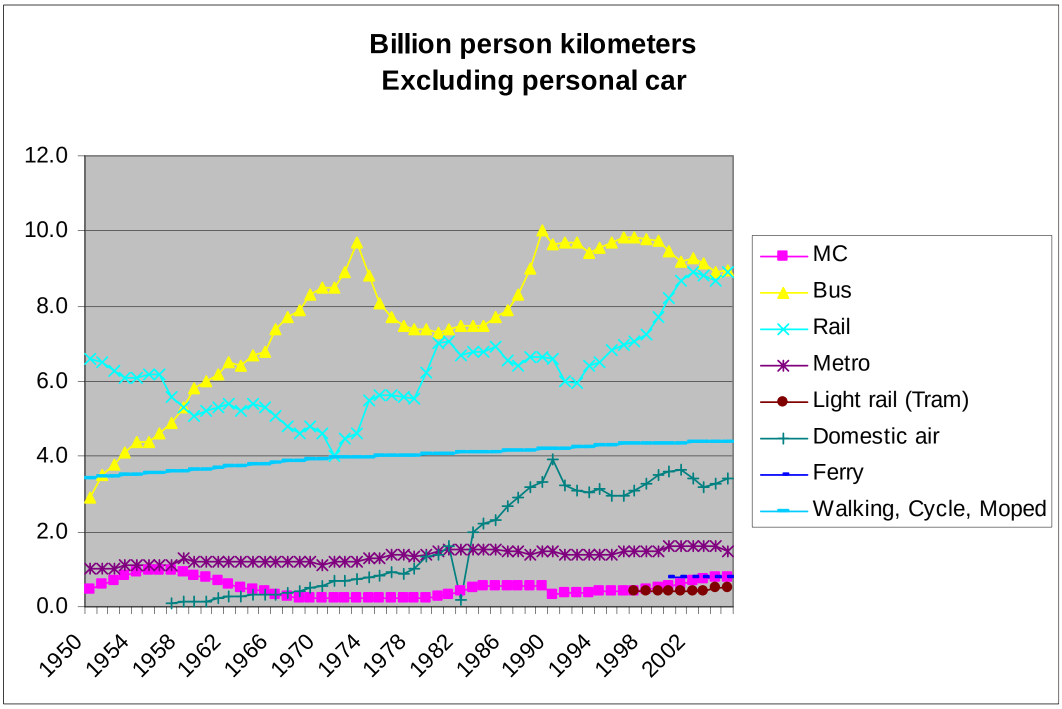


Figure 5. Driving licenses in Sweden by age group

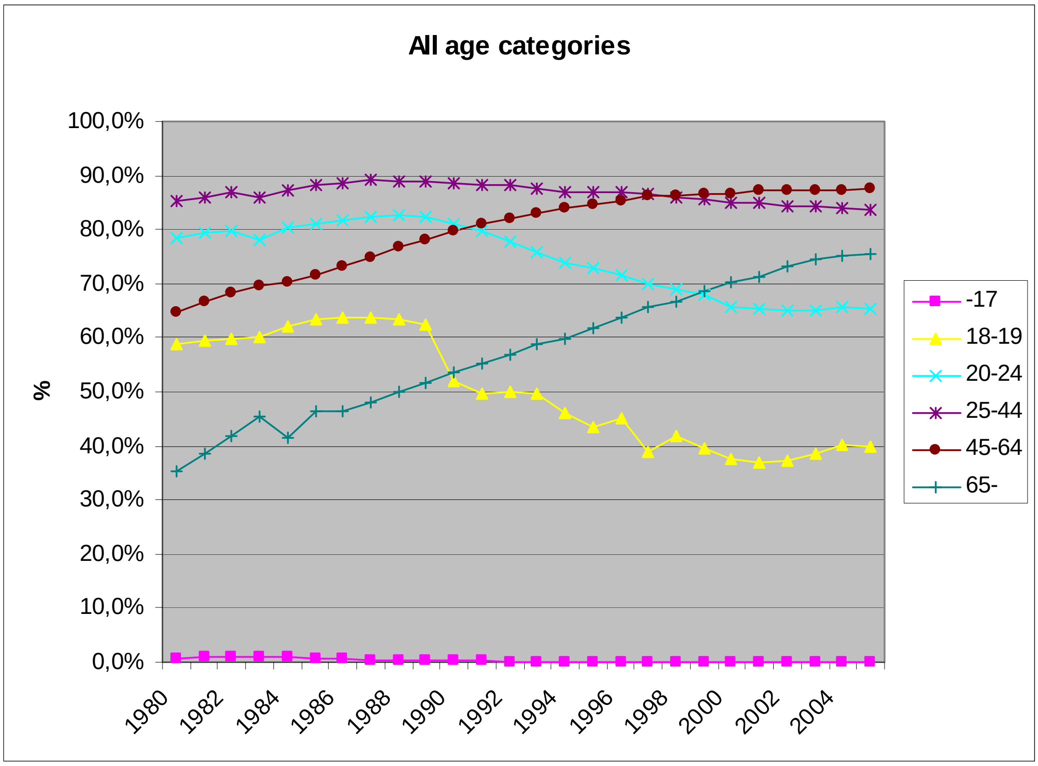
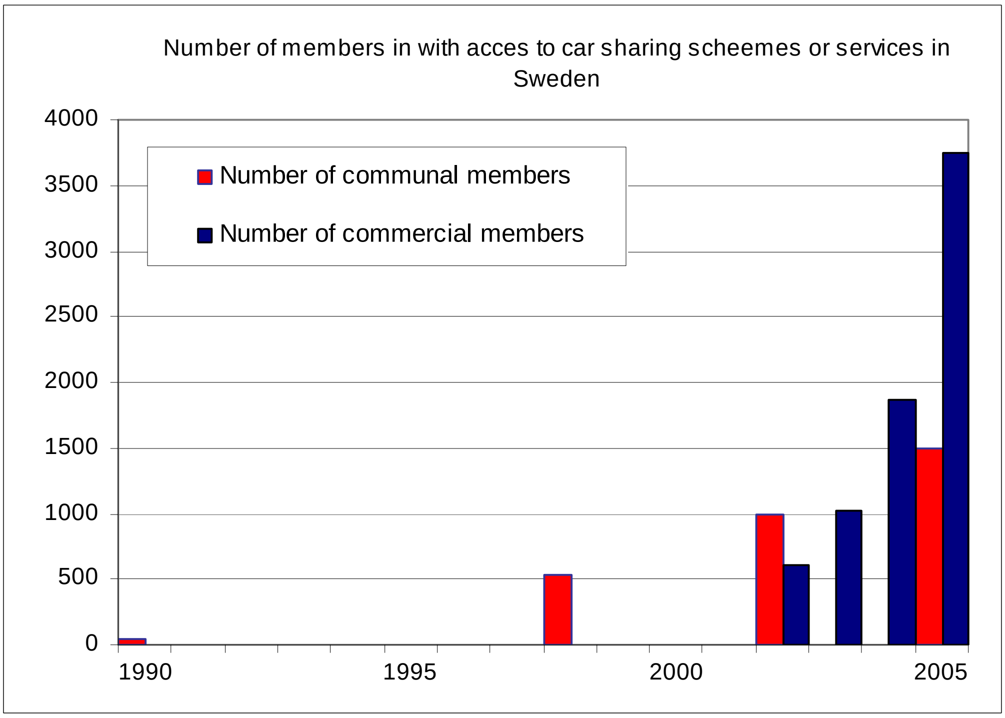


Figure 6. Communal and commercial Car share growth in Sweden



5.3.2 UK

Like Sweden, the UK has seen an increase in travel demand in recent years, particularly within private car use (Figure 7). The UK also has the same average kilometres per person per day (36) as Sweden (Strelow, 2006). However, the UK has a higher proportion of car use than Sweden, or the EU average, at 88%. Consistent with this, public transport use in the UK is lower than in Sweden, with 6% of travel accounted for by bus and 6% by train. Levels of walking and cycling ('slow modes') 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 10 Year plan.

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 (Strelow, 2006). In 1980, 41% of UK households did not have access to a car; this fell to 26% by 2003. The proportion of households having access to one car has remained stable over the last 25 years, at around 45%. However, the number of households owning two or more vehicles has increased significantly: from 13% in 1980 to over one-quarter of households by 2003 (Department for Transport, 2005b).

Nevertheless, as in Sweden, the proportion of younger people applying for drivers' licenses is dropping (Figure 8). Between 1990 and 2004, the percentage of 17-20 year-olds who held a licence fell from 43% to 26%. The UK Department for Transport (2005b) suggest this may be because the driving test has become more difficult (now involving a written theory examination, as well as a practical test; indeed, pass rates have dropped from 47% to 42% between 1994 and 2004) and/or increased costs of driving lessons and vehicle insurance. It is interesting to speculate about whether there is an emergent cultural shift away from the 'car-culture', as suggested by Nenseth (2005).

Car sharing and car clubs

The UK has seen a gradual increase in the establishment of car share schemes and car clubs in the past 5-10 years, although levels have not yet reached those of Germany and Switzerland. A recent Department for Transport study (2004) found some 480 reported UK-based 'closed' (i.e. (organisation-based, local, or regional) car sharing schemes (including groups of closed schemes within open car sharing schemes); over 40 'open' car sharing schemes; and 29 reported UK based car club schemes (of which 26 were active). Car clubs involve flexible access to hire of a vehicle; while car shares involve a driver and passenger(s) travelling from and to similar locations, and are often implemented as part of an organisational 'travel plan' to reduce car use.

Car leasing

Car leasing is widely available in the UK for both business and personal transport, offering consumers a means of running a new car for between around 2-4 years and then exchanging it for a new one (e.g., www.carleasing.co.uk, www.leaseacar.co.uk). Furthermore, a 'green' taxi company has recently opened in London: fleet cars are ICE-electric hybrids and all emissions are offset, while it claims that fares are no higher than other taxi firms (www.greentomatocars.com).

Teleworking

The UK government estimates that 8% of the workforce (3.1 million people) work from home or use their home as a base for work; this proportion has doubled since 1997 (Office for National Statistics, 2005). Of this total, 2.4 million can be considered 'tele-workers' (using a telephone and computer for their work), almost two-thirds of whom are self-employed and most of whom are professionals and managers. This is higher than the average EU-10 (see Figure 9), but lower than Sweden. The Institute of Employment Studies estimates that 22.6% of the workforce could potentially telework, the highest in Europe (cited in Hotopp, 2002).

Internet shopping
The proportion of UK households with internet access at home has risen significantly in the past few years: from around 10% in 1999 to 42% in 2002. Furthermore, the proportion of adults using the internet to buy goods and services is also increasing. UK government survey in March 2002 (Office for National Statistics, 2002) found 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). The most popular purchases were flights and holiday accommodation, books or magazines, tickets for events, and music or CDs. The survey also found that the main reasons for never having used the internet for shopping was that they had security concerns or that they preferred to shop in person. In February 2004, the figure had risen to 47% and in February 2005 it rose again to 56% (Office for National Statistics, 2006).

Figure 7a. Travel demand in the UK, by mode

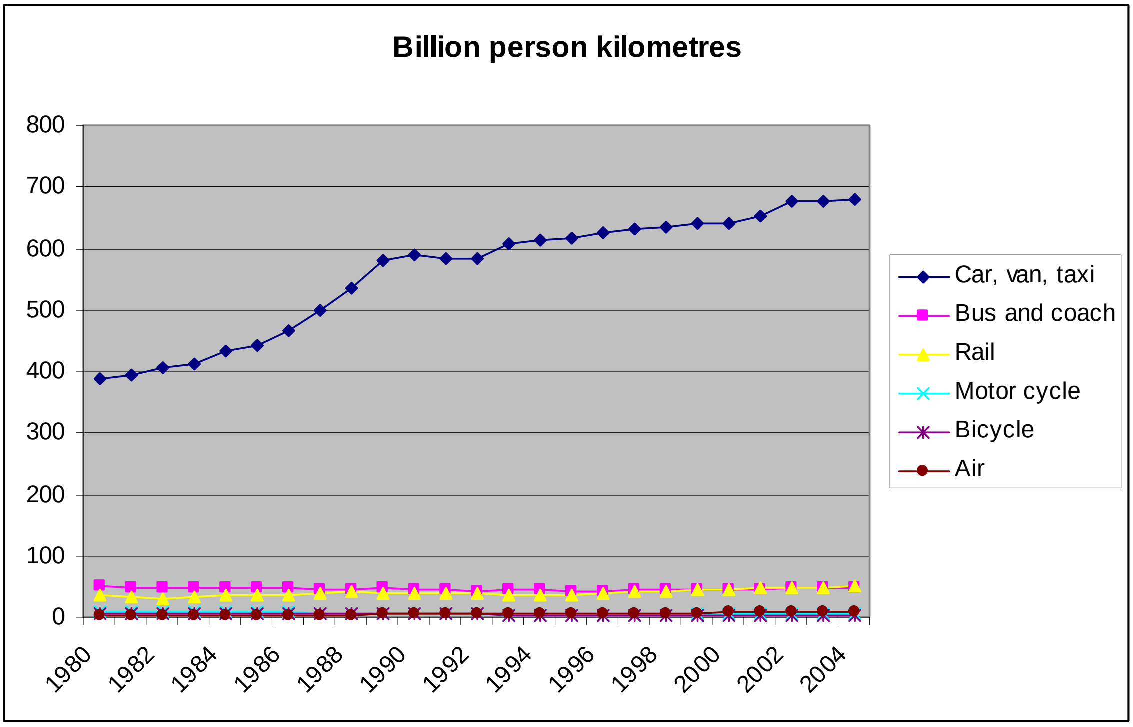


Figure 7b. Travel demand in the UK, by mode

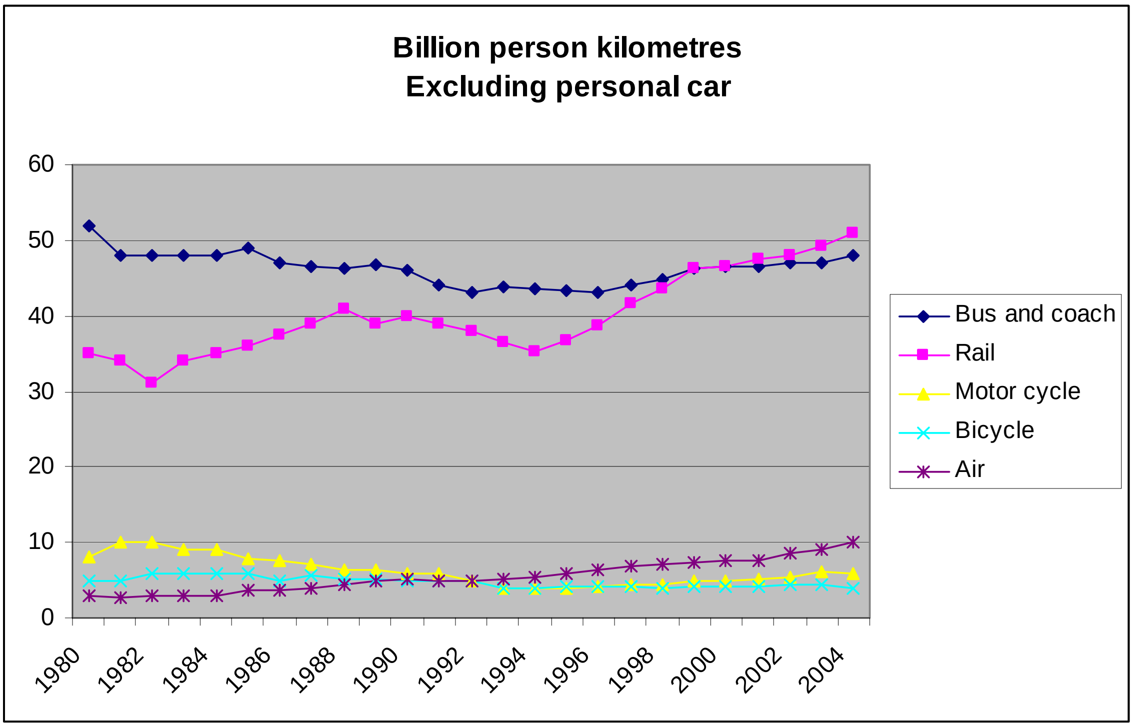


Figure 8. Driving licenses in the UK, by age group

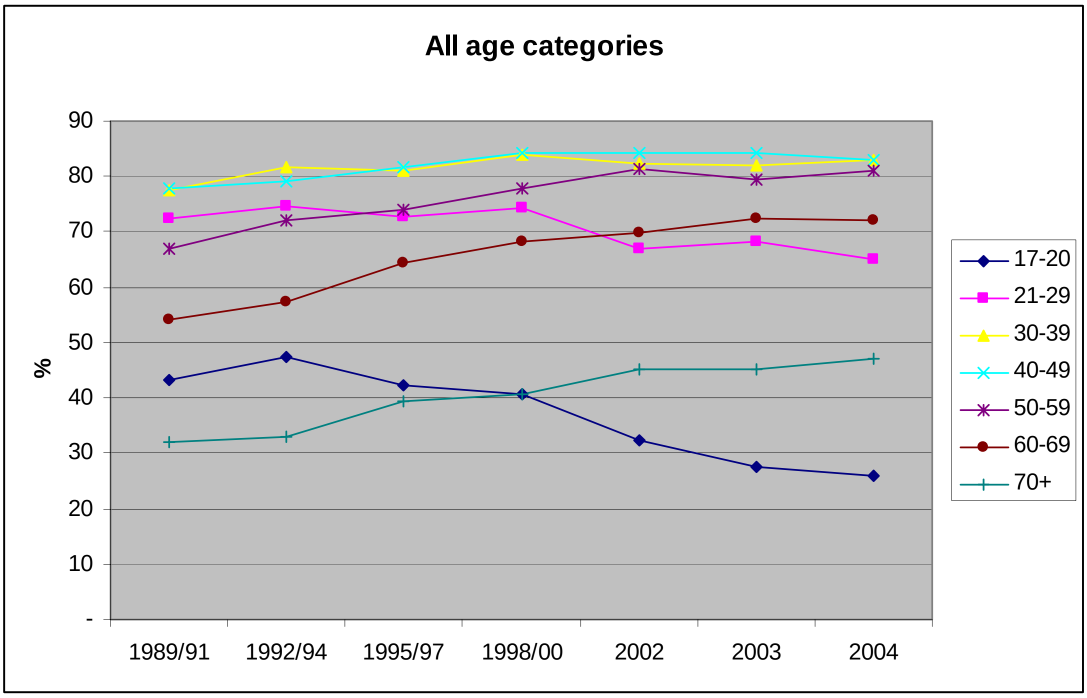
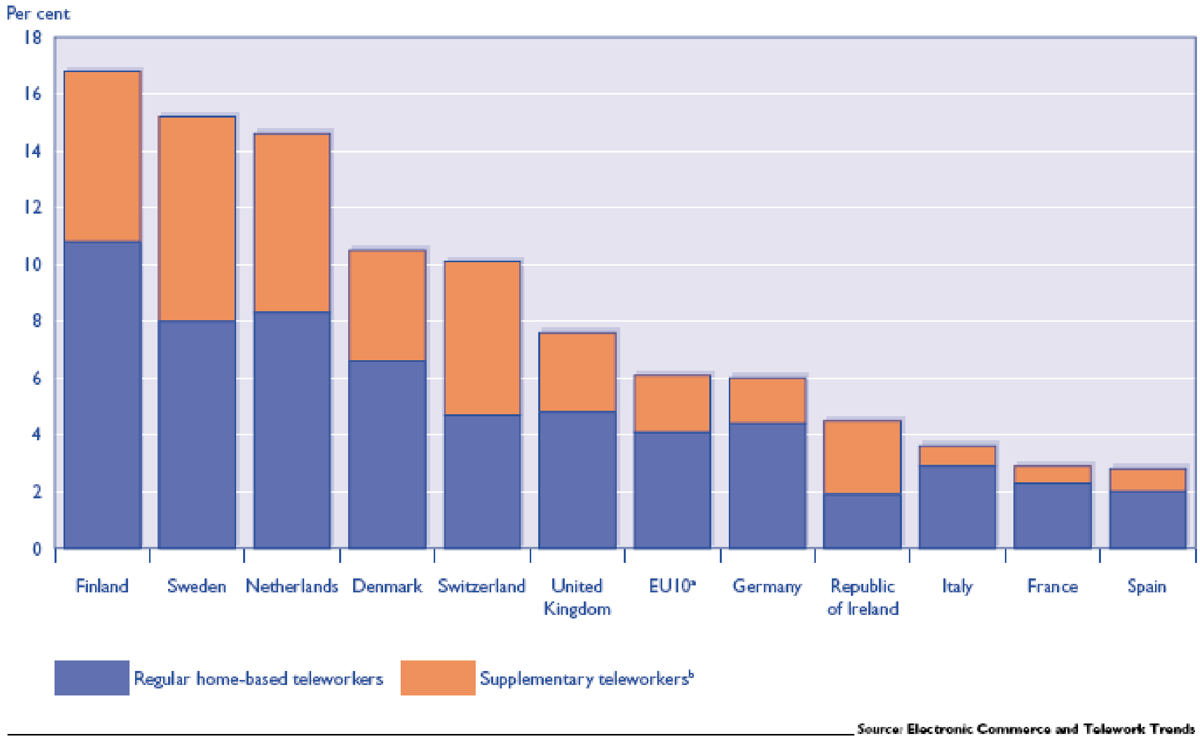


Figure 9. Teleworking in Europe



a The EU10 figure is an average of the ten EU countries represented in the chart. It does not include Switzerland.
b Home-based teleworkers who spend less than one full day teleworking from home a week.

5.4 Summarising empirical evidence

In Sweden, a takeoff in Niche 1 development can be observed. Several new technologies are gaining momentum, and figures suggest a rapid growth for current year and near term future. Although the Niche shows strength this trend is still at infancy and impacts have yet not materialised in terms of lower average CO2 emissions. Sweden still remains the top CO2 emitter per vehicle in the EU. The next few years will determine if the trend is capable accelerating, and have a true impact on the regime. Some notable Niche 2 activities and indicators such as increased car service, reductions in number of young attaining driving licence, and successful congestion charges support the image of active on going predevelopment in Niche 2. However, dependence on cars is still evident, with most of increase in travel demand supplied by cars. Within Niche 3, there are positive trends, but so far few indicators supporting the suggestion that increased use of ICT for home-shopping and home-work contributes to reduced travel demand. In terms of slow modes no substantial increase is visible and considering population growth the sector is in decline. There are also in effect drivers acting against Niche 3 development such as continued urban sprawl. In summary, although there is a growing awareness of this potential, few polices effectively fosters a Niche 3 development with the trial of congestion charges in Stockholm as a first notable exception.

In the UK, the empirical evidence suggests a slower growth in Niche 1 activities than in Sweden. Nevertheless, sales of low-emission and (to a lesser extent) alternative fuel/engine vehicles are increasing; and diesel cars remain very popular. As the biofuel infrastructure and industry develops this will facilitate market growth further in this area. The evidence for Niche 2 activities is somewhat ambiguous: while rail travel, car clubs and car shares are becoming more popular (as congestion and parking become more problematic), urban public transport use (e.g., buses) is somewhat declining while private car use continues to increase. Niche 3 data is similarly ambiguous: while home working and shopping are increasing, walking and cycling (slow modes) are declining. The political context - transport, energy and climate policies - in the UK may provide more support for development of all three niches, particularly if more powers are devolved to local authorities to implement schemes such as the London Congestion Charge.

Summing up, pre-development of several Niche 1 technologies is ongoing, while other novel technologies (notably biofuels in Sweden; and low-emission vehicles in UK) are already reaching the take-off phase. Niche 2 shows positive developments, but is still very much characterised by pre-development. Finally, developments of ICT in Niche 3 may support sustainable transport, yet slow modes are in decline.

6 Ongoing and future Niche accumulation within and between Niche 1, 2, and 3

Merging the analysis of the three discussed niches on novel technologies, a product to service shift, and trends in cultural and behavioural change, a basis for a more integrated analysis of future sustainable pathways for transport is established. In this section we try to highlight some key ongoing and potential niche-accumulation and hybridisation processes between the niches, and how such development contributes to the understanding of pathways to more sustainable transport.

6.1 Niche accumulation within the alternative fuel sector and importance of Niche 2 development

The current first generation of bio-fuels (ethanol, methane, and bio-diesel) paves the way for a second generation of more efficient synthesised biofuels such as DME and FTD (See Table 2), and energy carriers such as Hydrogen and Methanol. Furthermore, experiences with the gaseous fuel methane in terms of NG and Biogas and experiments with hydrogen rich fuels such as Hytane (Natural gas enriched with hydrogen), are an important interim step toward wide scale use of hydrogen as an energy carrier. Potential use of old methane infrastructure for Hydrogen supply and experience of gaseous fuels in general in terms of on-board storage, safety, and refuelling technologies, constitutes learning and potential technological add-on within Niche 1. There is also compatibility between bio-fuel development and the current (fuel/vehicle/auto-mobility) regime (Bomb, McCormick, Deurwaarder, & Kaberger, 2006). Similarly, as previously discussed, hydrogen and FC technologies are aligned with (developed within) the regime and early niche applications with respect to these technologies such as FC idle electricity generation in trucks (http://www.powercell.se) could pave the way for initial infrastructure build up.

6.2 Importance of Niche 1 and 2 co-evolving

The growth of new technologies and alternative fuels are ensured by a range of policy incentives, tighter regulations on particulate emissions, climate change policies etc. However, crucially, taxi fleets and public transport fleet experiments create initial infrastructure build-up and initial demand for new technologies. Furthermore, both car sharing schemes and rental cars can act to further promote new technologies. This is indicated in ongoing developments in Sweden where one of two actors in commercial car sharing uses environmental cars only[4], larger taxi companies continuously act as forerunners in procurement of alternative fuel and engine systems, and Toyota have implemented the subscription business model of the highly efficient Aygo model. That car services are in fact able to decouple engine size from travel service to some extent is also supported in the study by Prettenthaler and Steininger (1999). Even though impact of this trend so far is relatively small, this co-evolution between Niche 1 and 2 acts and can act as an important driver for new technologies also in the future. A continued product to service shift, strengthening car services procurement and car sharing could speed up diffusion of future technologies. Seemingly, alternative means of purchasing car services encourages new low cost and thus fuel efficient technologies.

6.3 IT as a driver in all three niches

By itself the car industry is unlikely to push for broad market introduction of alternative novel technologies. Regulation, developments in other sections (notably IT), and market demand (e.g., for functionality, branding, and new services) are key drivers for innovation as the car manufacturing industry has entered a mature state (Köhler et al., 2007; Seidel et al., 2005). In particular, IT and demand for additional functionality may lead to innovation in vehicles as mobile power platforms (e.g., Kurani, Turrentine, Heffner, & Congleton, 2003), in turn creating new support for electric drive trains found in HEVs and BEVs, or FCVs. In the transport service niche, IT enables new functionality in simplifying car sharing and car pool coordination. ITC is also a key driver in our third niche studied, offering communications solutions for potentially reducing transport need per se, but more importantly, restructuring culture and enforcing urban lifestyles through growing use and interests in IT throughout life and reducing importance of car ownership.

As IT acts as a driver in all three niches discussed, innovations associated with one of our discussed niches, could affect development in one or both of the others. Hybridisation and accumulation of IT solutions between these different niches could be a driver for further development within the niches.

6.4 Electric drive train development

It has already been discussed how an electric drive train could support new functionalities and create opportunities for niche accumulation. From a technological transition point of view, hybridisation and technological add-on between HEV, FC and alternative fuels are relevant here, and each of the technological options discussed in the literature constitutes innovative elements that enable further expansion, also for other related technological options in turn. With a growing share of the car fleet using an electric drive train, other opportunities for niche-accumulation and hybridisations could emerge. Research highlights HEV as an interim step to a plug-in HEV

[4] Sunfleet - http://www.sunfleet.com/

version acting as a purely electric car for longer distances before engaging the ICE. Furthermore, there is potential for plug-in cars to act as a buffer to energy system demand peaks (Kempton & Tomic, 2005). Finally, such niche accumulation could act as important first steps toward more advanced and automated electrified transport systems. With a large share of cars equipped with an electric drive train, and standards being developed, electrified highways, dual mode systems and other more futuristic options are one step closer to being realised (e.g., see Elzen, 2005).

6.5 Lifestyle change niche affecting other niches

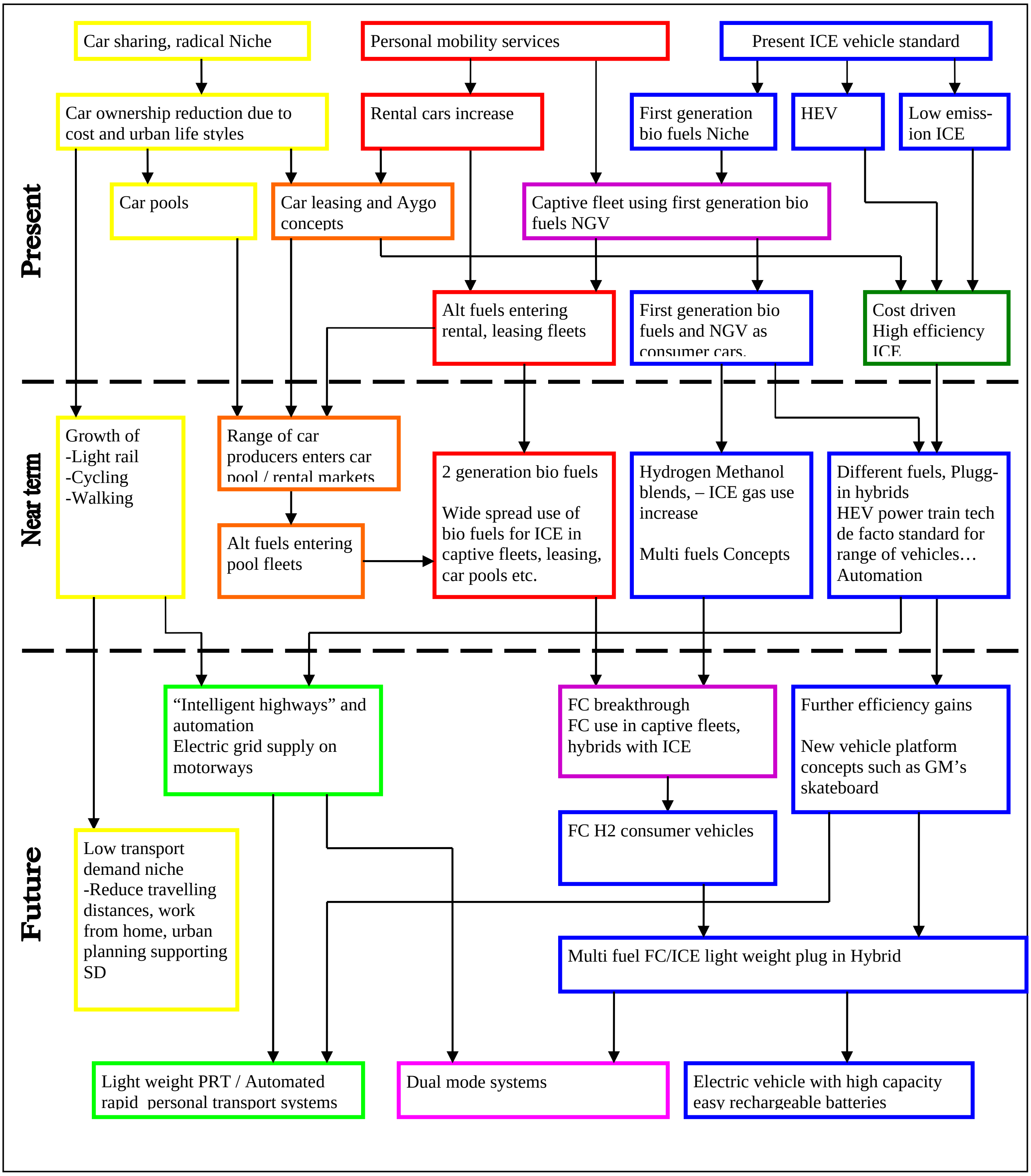
Behavioural and cultural changes within Niche 3, reinforced through wider landscape pressures and weakening of the transport regime, could act to slowly reduce transport demand in the mainstream through processes of social learning and imitation (Bandura, 1971). Hence, development internal to a radical Niche could spread values and environmental concerns to other consumers groups and encourage car manufacturers to speed up investments in new technologies through learning about innovations (cf. Smith, 2005). Existing links can also be exploited to develop more coherent networks of actors: for example, as mentioned, Niche 3 has obvious links with the product-to-service niche (Niche 2), which - in contrast to the current regime - also has little value attached to vehicle ownership.

6.6 Future niche accumulation and radical innovations

The ongoing and potential niche-accumulation processes discussed above highlight pathways to more sustainable transport solutions and use. In the following figure we have tried to illustrate both ongoing developments and some extended niche-accumulation and hybridisation possibilities between the discussed niches that could help introduce sustainable transport options. The purpose is to illustrate niche-accumulation and hybridisation processes that enable development and growth within and between the three niches. Illustrated pathways (arrows) and solutions (boxes) in the lower half of the figure are not to be interpreted as predictions but rather as possibilities that could enable more radical future sustainability solutions, considering evidence of similar ongoing and past processes. All three niches include potential ‘end states’ i.e. solutions that offers sustainable means of transport.

The figure is divided in three. The top section is ongoing; the middle section is near term development; and the lower section is possible longer-term niche development. Niche 1 is coded in blue boxes, Niche 2 in red and Niche 3 in yellow. When important (ongoing or potential) hybridisation in between them occurs, boxes are coded in respective mixes of colours.

Figure 10. Ongoing, near term and future niche-cumulation within sustainable transport



7 Conclusions

In this paper, we have outlined a number of serious and persistent problems in the current transport system, which suggest a need for a ‘transition’ - radical systemic change - towards sustainable transport. Furthermore, we have proposed three alternative niches which may lead us towards a more sustainable transport future in Europe, and examined evidence of the development of these niches in two European countries: UK and Sweden.

7.1 Theoretical implications

We believe that discussions of pathways to sustainable transport benefit from transition concepts such as niche and regime because they highlight important relationships between societal actors and trends which contribute to innovation and future development. Furthermore, temporal concepts of predevelopment, take-off and acceleration have enabled us to explore the dynamics and potential of different innovations.

Although we have focussed on niche development as a mechanism for transition to sustainable transport, we acknowledge that there may be circumstances in which transitions occur with minimal or no involvement of niche activities (Geels & Schot, 2005; de Haan & Rotmans, 2006). The historical evidence indicates, however, that niches - whether in symbiotic or antagonistic relationship with the regime - typically play a role in most transitions as they represent the source of radical innovation. Furthermore our discussion of the current transport regime's responses to landscape pressures indicates their reliance on niche innovation to adapt adequately. However, although we have highlighted various commonalities between and within our three niches, we have also found that actors within each niche do not necessarily have the same interests or compatible activities. In Niche 2 and 3 in particular, our empirical evidence highlighted several divergence trends which indicates these niches are unlikely (yet) to offer a coherent or stable alternative to the incumbent regime. This finding may indicate a weakness in our definition of these niches (and that alternative boundaries should be drawn around the transport 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 niches need not undermine the validity of our analytical framework.

7.2. Determinants of sustainable transport and implications for policy making

What have we found to be the determinants, or necessary conditions, for emergence and growth of sustainable transport niches? Firstly, they are determined by *landscape* pressures - both environmental (e.g., climate change), economic (e.g., oil prices, automotive 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). *Regime* actors are also beginning to respond to these pressures, and exploit technological opportunities and new markets (e.g., biofuels, HEV), and gearing up investments in even more radical technologies (e.g. hydrogen fuel cell vehicles); although there is evidence of misalignment and tensions between this group of heterogeneous actors. The regime is limited, however, in its capacity to respond to landscape pressures: for example, existing refuelling infrastructure and automotive expertise is not compatible with hydrogen transport technology development.

Such barriers to a transition can be partly avoided 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 niches opens up further radical development (e.g. product to service shift combined with new technologies).

Retaining the diversity of niches is important: combined policy and incentives, tax levels, and R&D encourage breadth of niche development. Different technological solutions are developed in parallel and finally a series of developments enables one of the technologies to break through. This is consistent with the notion of Strategic Niche Management (Kemp, Schot, & Hoogma, 1998), and notably the conditions for development within Niche 1 is now in favour of a breakthrough finally challenging the regime that was very stable in 1998 when Kemp, Schot and Hoogma analysed the transport sector.

It has been shown that CO2 emission reduction is less costly and more efficient if renewable energy primarily is used in other sectors than for road based transportation. (Azar et al., 2003; Hammerschlag & Mazza, 2005). These conclusions strengthen the arguments that it is dangerous to impose radical change, potentially building up new lock-in effects, with technologies using renewable energy where it is not as efficient as possible. In the end the transport sector has to undergo a wider transformation in order to become sustainable. However, as we have discussed in this article we argue that a regime change in the transport sector toward sustainability is best done when options are still kept open, with a wide range of Niches adding up and co evolving, using niche independent polices that foster such development.

Such policies must be seen to be effective by citizens if they are to be accepted and change attitudes and behaviour: the London Congestion Charge was not widely supported until it was introduced and seen to work. The same trend in acceptance could be seen during the experiment period for the Stockholm Congestion Charges. Policy measures less visible such as fuel taxation may not be as effective since its impact is less direct and its impact less obvious. Furthermore, congestion charging is an example of a policy that supports development in all three Niches: in Niche 1 – through exemption of tax for novel technologies; in Niche 2 – since the charges constitute an incentive for shifting to public transport; and finally in Niche 3 – through cost increase for unnecessary travelling inducing reduced travel demand. We identify two ways in which effective polices supporting a transition could be introduced. Firstly through gradual accumulation of initiatives guiding consumers toward alternative choices. In Sweden a range of such incentives and taxes have encouraged change since late 1990 when climate change became a prioritised policy issue and the first commercial alternatives to petrol cars become available. A similar process is taking off in the UK. Secondly, a single, more visible, and initially more controversial policy measure such as congestion charges can be decisive and have a broad range of impacts over different sectors than the primary one targeted, fostering wide niche development in unexpected sectors. The impact of the Stockholm Congestion Charges on environmental car sales in Stockholm has been notoriously underestimated.

Finally, we conclude that the role of Europe policy has not been straightforward. In many respects, the EU has been a driver of UK environmental policy development; however, it has in some aspects hampered development in Sweden – for example through not including the transport sector from the start in the CO2 trading scheme. A recent committee assessed the possibility to unilaterally press ahead, but concluded it would be difficult within the present agreement and with uncertain economic impacts on Sweden's economy, being the sole forerunner (Statens Offentliga Utredningar, 2005b, p70). A key role for Europe is to act on issues where lack of harmonisation among member states opens up for critique the often argued 'cost of being the forerunner'.

7.3 Achieving multiple sustainability goals

Sustainability in road transport also means relative sustainability in other sectors (cf. Whitmarsh & Wietschel, 2006), and indeed wider changes within society. Furthermore, since sustainable transport is a contested notion, it is important to foster participatory and integrated approaches to policy-making. No one policy can achieve the range of sustainable transport criteria outlined earlier; rather cross-sectoral policies and multi-stakeholder dialogue are required.

In this paper we have firstly addressed the three niches separately, and then discussed future co-evolution among them. It is unlikely that any one niche alone will be able to achieve sustainable transport: each contributes to different aims. For example, technology alone may not be able to provide the required emissions reductions to mitigate climate change (CST, 2001); furthermore, it does not address problems of congestion, obesity, and social exclusion, although it may provide the most economic opportunities of the three niches.

Much more radical solutions are needed in order to reach a sustainable transport future. It is impossible to project such solutions, but we have tried to outline some potential pathways and argued for the importance of supporting the breadth of solutions. A future sustainable transport sector probably includes both reduced demand through reorganisation of travelling patterns, alternative lifestyles and consumption patterns, and radical technical solutions.

7.4 Further work

The empirical findings from this research will be applied in simulation models of transitions to sustainable transport, currently being developed within WP9 of MATISSE (see Bergman et al., 2006). Potential "end states" of a sustainable transport transition will also be further examined, particularly drawing on stakeholder visions (e.g., Whitmarsh & Wietschel, 2006).

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