



Munich Personal RePEc Archive

Structure, agency and change in the car regime: A review of the literature

Marletto, Gerardo

Deir and Crenos, University of Sassari (I)

3 November 2010

Online at <https://mpra.ub.uni-muenchen.de/32134/>
MPRA Paper No. 32134, posted 10 Jul 2011 16:32 UTC



Structure, agency and change in the car regime. A review of the literature

Gerardo Marletto ^{1*}

¹ *UNU- DEIR/CRENoS - University of Sassari
Via di Torre Tonda, 34 - 07100 Sassari (I)*

Abstract

This paper is aimed at filling the gap between the already well structured literature on the 'car regime' and the debate on policies for sustainable transport.

Two main results emerge from the literature on the past and current evolution of the car regime:

- the car regime was established thanks to the ability of purposeful private actors to use the technology of internal combustion to influence markets and institutions, and finally society as a whole;
- previous attempts to make urban and regional mobility more sustainable fail because multiple - and mutually reinforcing - path-dependence phenomena lock the society into the car regime.

For the future, the dominant scenario appears to be the internal transformation of the existing car regime, which is currently driven by the automotive industry and based on hybrid technology; the emergence of an alternative electric car regime - driven by producers of batteries and managers of electric utilities - remains a secondary option.

Further research is needed to understand how - starting from the existing alternatives to the car and the innovations in the car itself - a coalition of public and private actors may be promoted and sustained to create a new regime of sustainable mobility.

Keywords: Car-based mobility; Regime; Sustainable Transport; Transport Policy.

1. Introduction

This paper shares the diffused perception that a new approach to transport policy is needed to meet the challenging goals of long-term sustainability of human activities, at both the global and local level (Akerman and Hojer, 2006; Köhler, 2006; Hickman and Banister, 2007; Moriarty and Honnery, 2007; Bristow et al., 2008; EEA, 2008; McCollum and Yang, 2009; Stanley et al., 2009). It also agrees on recognizing that the institutional, technological and economic dimensions of transport activities should be

* Corresponding author: Gerardo Marletto (marletto@uniss.it)

considered, in order to design and implement effective policies for their sustainability. Two strands of transport research on this topic can be identified in the literature¹. The first one is based on neoclassical and new institutional economics: authoritative researchers acknowledge the need to extend the theoretical apparatus in order to include institutional and technological issues into the analysis of transport policies. But results are somewhat disappointing: institutions are considered nothing but barriers to be overcome by integrating policies or by increasing their acceptability (Rietveld and Stough, 2005; Vieira et al., 2007; Banister, 2008; May et al., 2008; Hickman et al. 2010); technologies are relevant - especially when considering environmental impacts - but they still remain exogenous (Litman, 2005; Goldman and Gorham, 2006; Johansson, 2009); even competitive mechanisms - both spontaneous and policy-driven - are not part of a genuinely dynamic process of change, but rather the only available way to escape market and state failures (Button, 2005; Raux, 2007). The second research strand considers the co-evolution of institutions, markets and technologies as the core process of the dynamics of transport activities. A structural approach to the analysis of endogenous process of change is developed, with reference to: past radical and incremental transport innovations (Geels, 2005b); technological, economic and institutional niches where transport novelties can take the first steps (Hoogma et al., 2002; Ieromonachou et al., 2007; Nykvist and Whitmarsh, 2008); transitions towards more sustainable ways of moving freight and passengers (Schot et al., 1994; Kemp and Rotmans, 2004; Kohler et al., 2009).

More recent insights from institutional (North, 2005; Hodgson, 2006)², Schumpeterian (Metcalf, 2010; Dosi and Grazzi, 2010; Perez, 2010) and Hicksian (Amendola and Gaffard, 2006) theories of endogenous change - helps to show that past, on-going and future dynamics of transport activities can be analysed by using the concept of 'regime': i.e. a system which is able to meet overall societal demands and whose structural components (rules, artefacts, services, preferences, interests, etc.) are reproduced and changed through individual and collective actions and learning. Consistently, policies for sustainable transport are conceived as actions to 'unlock' the existing car regime and to trigger and to make viable its change by ensuring the dynamic alignment of new structural components.

The rest of the paper is divided into three sections: in the next one a simple conceptual model is used to represent the structure and the dynamics of a regime; the following section reviews the relevant literature, showing that such a model has already been used to successfully analyse the evolution of the car regime. The last section takes stock and suggests that - if one wants to unlock the existing car regime and create a new regime of sustainable mobility - the issues of public and private agency deserve a better understanding.

¹ As always happens with theoretical taxonomies, boundaries are not clear cut. For example, the paper of van den Bergh et al. (2007) is very difficult to classify and should be considered as a 'bridge' between the two strands discussed.

² Is under dispute if Douglas North is an institutional or new institutional scholar, but most studies agree on considering its work as a theoretical evolution from the latter to former (see, among others, Zweynert, 2009).

2. What is a regime and how it changes: a simple conceptual model

Regimes are systems that have a pervasive (or dominant) effect on reality, by fulfilling an overall social function (feeding, housing, production, transportation, etc.):

“(...) a societal function encompasses the expression of a human need and the way in which this need is met. Thus a regime consists of all actors and elements that are involved in originating, shaping, fulfilling this need and/or in regulating how this happens.” (Holtz et al., 2008, pp. 626-627)

The functioning of regimes can be conceptualized as structured agency (Giddens, 1984): a structure of three interrelated dimensions - that is, institutions, technologies and markets - is replicated and changed through individual and collective action and learning. Because each of these structural dimensions has its internal dynamics and a relative autonomy, they can be considered as sub-regimes which are linked by a co-evolutionary process and generate bi-lateral and tri-lateral relations (Geels, 2004; Holtz et al., 2008)³. Change at the regime level is coordinated by its structure and it is driven by cumulative agency; in other words: action and learning are enabled and constrained by structural variables. Strong uncertainty and irreversibility are ineradicable features of the dynamics of regimes. Each of these concepts needs to be better explained.

2.1 The structure

Let us start from a thorough analysis of the three structural constituents of a regime: institutions, technologies and markets.

Institutions are nothing but general rules that structure social interaction⁴; both tacit and explicit rules can be observed only through manifest behaviour (i.e., ignored formal laws are not rules) (Hodgson, 2006). The enforcement of rules and the sanction of violations is driven by legal or social mechanism. New rules may emerge from intentional and unintentional action; obviously it is easier and quicker to change formal rules than informal ones.

Technologies are “configurations that works” (Geels, 2005b, p. 11): they are made of artefacts (if any) and routinised knowledge, and they fulfil one or more functions. Technologies are invariably systemic and almost always embedded in a specific environment of economic and non-economic organizations and networks (Cimoli et al., 2009). Technological change is mostly cumulative, it is driven by a collective heuristic (a 'paradigm') and it is shaped by several factors, among which learning (by doing, by using and by interacting) plays a crucial role (Dosi and Grazzi, 2010).

Markets are more than mere exchange mechanisms: they act as the selective environment of technological innovations (Nelson and Winter, 1982) and play a relevant role in coordinating all economic decisions during innovation processes (Amendola and Gaffard, 2006). In these cases it is not possible to say ex-ante that mutually consistent changes in producers' expectations, financial resources, labour

³ Similar interacting sub-dynamics (though between industries, universities and governments) are at the heart of the so-called 'triple helix' approach (Leydesdorff and Meyer, 2006).

⁴ Actually, each sub-regime has its internal rules; here we are considering rules that are relevant at the regime level.

skills, consumers' preferences - and so forth - will make the innovation process viable (Amendola and Gaffard, 1998; Metcalfe, 2010; Safarzyńska and van den Bergh, 2010a).

Now we can analyse the three mutual relations between the above mentioned components of the regime:

1) Institutions and technologies. As suggested by the huge literature on innovation systems, institutions and technologies co-evolve:

“Some institutions provide the broad background conditions under which technological advance can proceed, and others come into existence and develop to support the important new technologies that are driving growth.” (Nelson, 2008, p. 2)

Institutions technologically relevant are both explicit (laws and regulations about patents, innovation policies, standards, etc.) and tacit (how universities and firms cooperate, how venture capitalists evaluate potential innovations, etc.).

2) Technologies and markets. The analysis of this interaction is rooted in the Schumpeterian theory on innovation and competition: the emergence of new technologies and the structure of markets are strictly linked and give place to pervasive effects of 'creative destruction'. The innovation process influences and it is influenced by almost all economic variables: the internal organization of firms, the competitive structure of industries and markets, the matrix of vertical and horizontal inter-firms and inter-industries input-output relations, the dimension and the structure of innovation networks of economic and non-economic agents, etc. (Freeman and Soete, 1994; Pavitt, 1999). This mutual influence is heavily conditioned by the main features of the changing technology (Silverberg et al., 1988, p. 1033).

3) Markets and institutions. This interaction has been studied by institutional economists: Coase and Williamson have stressed the relevance of transaction costs; North has studied how institutions influence economic performance; Buchanan and Stigler have analysed how deregulated markets may reduce the risk of both market and State failures. But it is only with the latest studies of Douglas North that a really dynamic approach is proposed: institutions and markets are explicitly considered as interdependent dimensions of the process of economic change, and the misalignment of institutional and market adjustments is proposed as the main cause of economic crises and stagnations (North, 2005).

2.2 Agency and change

Agency is an essential element of the dynamics of regimes: individual and collective action replicates the structure of the regime, whilst generating - directly or indirectly, intentionally or unintentionally - the variation of structural variables. Evaluating the ability of actors to build or strengthen coalitions and to influence actual changes, it is possible to discriminate among core actors, non-core actors and outsiders (Smith et al., 2005; Hajer and Laws, 2006; Zweynert, 2009). Strategic action is not the only element that distinguishes the dynamics of regimes from a genuine Darwinian evolution, the other one is the iterative process of learning: actors found future actions on current results (Hodgson and Knudsen, 2006). Both action and learning can be individual and collective; through learning: a) groups and coalitions update shared discourses, visions and agendas; b) individuals change their attitudes, beliefs and expectations; and c) they

may decide to migrate between groups (Ostrom, 2000; Witt, 2008; Safarzynska and van den Bergh, 2010b).

Thus the functioning of a regime is genuinely dynamic and path dependent, featuring irreversibility and strong uncertainty⁵: future changes are neither completely uncertain (as the potential developments of the existing regime are limited by its structure) nor completely certain (as the interaction of structural variables and agency may generate unpredictable outcomes). As brilliantly stressed by North, the dynamics of regimes is more than uncertain: it is non-ergodic (North 2005, ch. 2): even changes in the fundamental structure of the regime are usual features of its dynamics. In such a context it is no longer possible to consider agency as driven by complete information: on the contrary, agents' rationality is bounded and adaptive, and their behaviour is not optimizing, but satisfying (Nelson and Winter, 1982; Simon, 1987). The cumulativeness and irreversibility of regime changes - together with network interdependencies and the externalities they bring about - often generate lock-ins, that is, the creation of new regimes is an exceptional case. These phenomena have been thoroughly studied with reference to technologies and markets (Unruh, 2000); actually they may also generate behavioural conformism (Maréchal, 2010) and institutional sclerosis (North, 2005). The lock-in of regimes can not be fully understood without explicitly considering core actors implementing conservative strategies; the 'capture' of public organizations and the 'entrapment' of policy agendas is probably the more relevant way for them to resist change (Unruh, 2000; Walker, 2000; Berkhout, 2002).

Several scholars have tried to select the essential elements of the dynamics of regime change and to propose a taxonomy of regime changes, but a shared and stable framework has not yet been reached (Geels, 2005a; Smith et al., 2005; Geels and Schot, 2007; Bergek et al., 2008; Genus and Coles, 2008; Markard and Truffer, 2008). However, some theoretical hints may be given starting from a basic question: which are the sources and the outcomes of regime change? Sources of regime change can be both internal and external to the regime itself. In the former case, change is more often driven by internal (core and non-core) actors; in the latter, outsiders usually play a relevant role⁶. Outcomes of regime change may be grouped into two large families: the adaptation of the existing regime and the creation of a new regime. Adaptation can be conceptualized as an homoeostatic process: cumulative changes in institutions, markets and technologies take place along a dominant trajectory, without altering the internal consistence of the regime itself. Things radically change in the case of the creation of a new regime: no structure is available to coordinate a new process of multidimensional alignment, because the structure itself is created through change. Homoeostasis is replaced by complexity (Arthur, 1999). In such a situation, one can even doubt if the creation of a new regime is possible without the purposeful and increasingly coordinated action of powerful 'prime movers' - or 'enactors' - committed to change (Jacobsson and Johnson, 2000; Suurs et al., 2010). This is why some scholars - especially in the context of transitions to a low carbon society - have suggested that the creation of new regimes must be adaptively managed through reflexive governance and societal learning (Voß et al., 2006; Loorbach, 2007; Foxon et al., 2009; Nill and Kemp, 2009; Voß et al., 2009). Niches are essential in the case of the creation of new regimes, not so much to incubate market and technological novelties, as to gradually build up -

⁵ Strong uncertainty is equivalent to the game theory concept of 'ambiguity'.

⁶ As stressed by Smith et al. (2005) outsiders in a regime may be core actors of a competing regime.

and legitimate - a coalition of actors sharing a vision and a political discourse, and advocating all changes needed to create a new regime (Schot and Geels, 2007). A trade-off between the opening of several niches and the pursuit of only one innovative path is apparent; in the former case there is a risk of not achieving the critical mass necessary to establish a new regime, in the latter of reinforcing lock-ins in an unsustainable regime (Berkhout, 2002; Rammel and van den Bergh, 2003; Sartorius, 2006). The more recent critical literature on the approach of transition management calls for more attention to political and institutional issues, especially to the ability of supporters of transitions to promote new discourses and broader coalitions for social change, with the aim of overcoming incumbent powers and generating a radical change in everyday politics and policy (Shove and Walker, 2007; Meadowcroft, 2009; Smith and Kern, 2009).

3. Retrospect, status and prospect of the car regime

This section is aimed at analysing the literature on the car regime; but, before starting the review, one should answer a preliminary question: does the relevant literature recognize the car as a regime? Yes, it does. First of all, one may notice that, in a recent paper aimed at a better specification of the concept of regime, authors explicitly refer to the 'car-based mobility' as a regime:

“We consider the currently dominant mobility system to be a regime which is based on individually owned cars, gas, service stations, streets, traffic regulations, preferences like flexibility and the perception of cars as being also life-style objects. Its main societal function is to satisfy the need for mobility. It is coherent: the technological elements like cars, streets, service stations, the kind of gas provided etc. are strongly adapted; the design of cars is not only defined by technical aspects but also through consumers' preferences; laws, taxes and insurances guide and bound the usage of cars. It is dynamically stable: there have been some trends like technological improvements (e.g. anti-locking systems, catalytic converters and navigation computers, just to name a few), or an increasing number of cars per household; but the general pattern remains stable. It shows non-guidance since many and diverse actors are involved: car manufacturers, oil companies, various national ministries, car owners, associations etc.” (Holtz et al., 2008, p. 629)

Moreover, one may add that scholars from different disciplines recognize that the car is a regime (even though they may name it differently). Frank Geels - an expert of the history of radical innovations (whom we will refer extensively in the following paragraph) - reports that in the early 20th century:

“The diffusion of cars was accompanied and made possible by the creation of a new socio-technical regime that was tailored to its demands. New regulations were one element of this regime, often reformulated in favourable ways. (...) Another element of the new socio-technical regime was the improvement of road infrastructures. (...) As the car diffused it had wider impacts on society. It facilitated the emergence of a ‘car culture’, supported by new institutions such as fast food restaurants on highways, shopping malls on the edge of cities,

drive-in movies. (...) The car developed many forward and backward linkages in the economy of the 1930s. The automobile industry was a huge consumer of sheet steel, glass and paint, components (tyres, lamps, generators, etc.), and machine tools. The use of the car boosted the petroleum industry and construction and public works (roads, bridges and tunnels). In sum, the car became strongly embedded in society.” (Geels, 2005b, pp.467-8)

Michael Best - an economist that pioneered the issue of the societal lock-in in suboptimal patterns of production and consumption - argues more directly that:

“If the car, for example, were simply a commodity, then it could be taken or not with a minimum of social consequences. But it is more than a commodity, for it is part of a way of life. Once it has become the dominant mode of transport then housing, family, work, shopping and recreation patterns are designed around it. Not consuming the car is like rejecting a religion into which one was born. It disconnects a person from the social fabric of society.” (Best, 1982, p. 61)

John Urry - an authoritative sociologist of mobility - adds that:

“(...) automobility is a self-organising, non-linear system that (...) generates the preconditions for its own self-expansion, including elements, processes, boundaries, and other structures, and the unity of the system. (...) billions of agents co-evolve and adapt to form a system of interdependent agents and relations—a complex assemblage or system that ‘constitutes’ the ‘steel-and-petroleum’ car.” (Urry, 2008, p. 343-4)

Paul Nieuwenhuis and Peter Wells - two of the most authoritative experts on the automotive industry - may then consistently stress that:

“(...) it is important to recognise the car as part of a system (...) which we have called the ‘automobility paradigm’. It is often not appreciated to what extent our modern culture is integrated with the car and its systems: we have literally built our world around the car in its current form (...).” (Nieuwenhuis et al., 2004, p. 10)

Starting from this basic considerations, in the following paragraphs a specific attention will be given to those contributions that explicitly make reference to the salient constituents of the car regime, that is: a) the interaction of institutional, technological and economic variables in the history of the car regime; b) the crucial role of agency, with a specific attention to the ability of core agents to establish the car regime; c) the existence of path-dependence and lock-in phenomena in the current evolution of the car regime; d) the consequent need of powerful actors and factors to trigger a process of radical change and to make viable the (re-)alignment of institutional, technological and economic variables (that is, to create a new regime or to adapt the existing one).

3.1 When the car was born: a multidimensional history

The advent of the car has attracted several scholars; but it is only with Frank Geels that the interaction of institutional, technological and socio-economic variables is explicitly and systematically considered. It is then natural to start this literature review with his study about the transition from horse-drawn carriages to cars that took place

during the period 1860-1930 (Geels, 2005a,b)⁷. The main aim of Geels's work is to show that the historical dynamics of such a transition was neither a simple substitution process, nor was the result of a competitive battle that the gasoline car won against the already existing steam and electric cars. Geels explicitly considers “other aspects such as policies and regulations, user preferences, infrastructures, cultural and symbolic meanings” (p. 448).

Four main results emerge from his work. The first one is that societal pressures and needs ('landscape changes' in Geels's terminology) weakened the existing regime of horse-powered transport. Probably the main cultural pressures came from “the increasing attention in public debates for health and hygiene” (p. 456) in expanding and more and more crowded, congested and dangerous cities. Obviously, the horse manure was perceived as one - maybe the worst - enemy for this salvationist movement. The second main result of Geels' studies is that several alternatives to the horse carriage developed before the internal combustion car become the dominant mode of urban transport of passenger (that is, a new regime). Some, like the electric tram, diffused rapidly: “In 1890, 16% of American street railways were electrified (...). By 1902, 97% of American street railways were electric” (p. 458). Others conquered market niches: the electric car in the urban niches of taxies and promenading in parks; the bicycle in the niche of touring; electric and gasoline cars in the niche of racing. The gasoline car started in a niche too: that of touring in the countryside; only gradually it gained new market segments: urban taxies, businessmen (doctors, travelling salesmen, insurance agents, etc.), farmers, middle-class suburban residents. The third relevant conclusion is the recognition of agency, especially with reference to the role of economic and social actors, both in creating new markets and in promoting the rules and policies consistent with their development. First of all it must be said that the option of an electric car system (made of batteries, vehicles and a recharging infrastructure) was abandoned well before its technological and commercial feasibility was tested: “the electric vehicle was sabotaged not by its competitors, but by its custodians, that is, the Electric Vehicle Company” (Black, 2006, pp. 80-81). EVC jumped from electric to internal combustion cars when it found out that only in the latter technology one basic patent was enough to control the market and earn royalties from all car producers.⁸ But no intentional action can be compared to the prolonged and multi-fold policy effort that accompanied the diffusion of the gasoline car, after its initial promotion. The car was increasingly regulated (car tags, driving license, speed limits) but, at the same time, it became the exclusive 'king of the road', confining pedestrians to side-walks (and children to newly built playgrounds). Urban streets were first improved, using concrete and asphalt; then they were widened and connected through bridges and underpasses; finally “the first highways were built in and around cities, e.g. on Long Island in 1914 and the Bronx in 1923” (p. 467). Changes in norms and institutional bodies took place too: “the traditional local right of local residents to administer their streets was gradually eroded and transferred to local authorities” (p. 459) and “in 1916 President Wilson signed the first Federal Aid Road Act into law, creating the new Bureau of Public Roads (BPR)” (p. 468). The last - and probably most important - result of Geels's analysis is that many

⁷ All following quotations are taken from Geels (2005b).

⁸ Actually this happened until - more than twenty years after - Henry Ford did not convince the US patent office that his car was based on another technology (the Otto engine instead of the Brayton, developed by the EVC).

of the above factors mutually reinforced: new social values and attitudes, new rules and new institutions, new actors and new coalitions of actors, new forms of urban development and new infrastructure, and an increasingly refined artefact for individual transport, gradually aligned, thus paving the way towards the creation of the internal combustion car regime.⁹

3.2 *The car as a regime: the role of core actors*

Actors whose main interests were directly dependent on the diffusion of the car - that is, 'core' actors - were among the more powerful factors for the establishment, reinforcement and reproduction of the car regime. The role of core actors is particularly apparent in three moments of the American history of the car regime: the dismantlement of the trolley system in the 1930s; the creation of the federal highway system after World War II; the radical amendment of the first Californian mandate for low- and zero-emissions vehicles in the 1990s.¹⁰

About the abandonment of the electric tram as the main urban transport mean in the USA, it is worth referring directly to the words of two scholars of the issue:

"In the 1920s the US had rather extensive trolley, transit and rail systems. But the competition among product forms was short lived, as documented by Snell¹¹. First, General Motors (GM) gained control of all forms of ground locomotion in the country. Then during the middle of the decade GM, often in conjunction with Standard Oil of California and Firestone Tyres, launched an investment programme enabling it to control and dismantle the electric trolley and transit systems of forty-four urban areas in sixteen states. The three corporations acquired electric rail systems, uprooted the tracks, and substituted diesel powered bus systems." (Best, 1982, p. 58)¹²

"(...) Snell asserted that GM's true motives were not just to convert electric trolley systems into bus lines so it could sell more diesel buses and eliminate competitive electric systems, but also to then cause the abandonment of those very bus companies, thus killing mass transit altogether." (Black, 2006, p. 200)

Also in the case of the US highways program, to describe the role of core actors is best to refer directly to scholars of the issue:

"US government officials were lobbied for road building projects by a large network of institutions that included the Portland Cement Association, the American Automobile Association, the American Road Builders Association, the Association of Highway Officials, the Rubber Association of America, the National Paving Brick Association, the

⁹ On this specific point see also Unruh (2000) and Rao (2004).

¹⁰ The role of core actors in the US car regime is just an example of what has been experienced in several industrialized countries. About the Italian case see Maggi (2005) and Paolini (2007).

¹¹ Bradford Snell was the staff attorney of the US Senate sub-Committee on Antitrust and Monopoly that in 1974 accused GM of a deliberate action against mass transit systems.

¹² It must be said that the action of GM was facilitated by the negative public image of trolley systems, which was due to a greedy private management and a too strict public regulation. On this point see again Geels (2005b, pp. 463-4, 466).

National Automobile Chamber of Commerce and scores of others.” (Unruh, 2000, p. 825)

“The United States federal government, responding to these pressures, diverted its entire transport budget to roads between the years 1944 and 1961.” (Best, 1982, p. 58)

“The secretary of defence¹³ marshalling the great new highway expansion was Charles Wilson, who from 1941 to 1952 had served as president of GM.” (Black, 2006, pp. 248-9)

The Californian mandate for zero-emission vehicles was adopted in 1990 in order to improve air quality¹⁴. Before its adoption, there was no strong opposition from auto-makers and oil companies, because the mandate was considered a minor part of a more general policy; the preliminary debate dealt more with other and more immediate requirements, such as less polluting fuels and low- and ultra-low emission vehicles (Sovacool and Hirsh, 2009). But in a few years things changed:

“General Motors and Honda responded by initiating research aimed at mainstreaming electric vehicle production. (...) Other automobile companies and the American Automobile Manufacturers Association (AAMA), however, mounted a two-pronged attack on the CARB mandate. First, the AAMA claimed that alternative vehicles would be too costly for consumers, (...). Automotive companies also claimed that Evs provided no significant environmental benefits. (...) In concert with these moves, a consortium of major oil companies (including Exxon, Shell, and Texaco) contributed in 1994 and 1995 more than \$1.1 million to legislative candidates in California in an attempt to weaken the state’s push towards electric vehicles; the Mobil Oil Corporation spent an additional \$3.5 million in advertisements aimed at discrediting potential alternative fuel vehicles. The oil industry did not limit itself to mere advertising, however; it also resorted to ‘greenwashing’ and ‘Astroturf lobbying’ (a strategy by which corporations attempt to conceal their involvement in lobbying behind the façade of faux grassroots groups) by establishing three organizations designed to influence public opinion against alternative vehicles. These efforts apparently convinced CARB to capitulate, and in 1996, it rolled back the electric vehicle mandate by five years. Further reviews by CARB have delayed introduction of electric vehicles, with emphasis on the development of hydrogen fuel-cell cars instead. But even the promise of such vehicles has recently faded (...).” (Sovacool and Hirsh, 2009, p. 1101)¹⁵

3.3 Locked into the car

Seminal studies on path-dependence and lock-in phenomena in innovation processes, explicitly refer to the success of the gasoline car as the result of cumulative events

¹³ After World War II the interstate development came under the portfolio of the US secretary of defence.

¹⁴ A detailed analysis of the mandate can be found in Kemp (2005). About other European initiatives to promote electric vehicles see: Hoogma et al. (2002, ch. 4), Calef and Goble (2007), Kemp et al. (this Issue).

¹⁵ On this issue see also Calef and Goble (2007).

triggered in the early years of automobility. For example, this is how Brian Arthur introduces one of its first papers on the subject:

“It is possible, of course, that gasoline possessed hidden engineering advantages that were only slowly uncovered. But another, quite different explanation can be put forward. Very often, technologies show increasing returns to adoption - the more they are adopted the more they are improved, and the more attractive they become. (...) When increasing returns are present, it is often a mistake to explain adoption by the 'superiority' of the technology (...) an industry (or economy) can get 'locked-in' to a technological path that is difficult to get away from.” (Arthur, 1984, p. 10)

Such an approach has recently been applied to environmental matters by Unruh (2000), who considers the car regime as a relevant example of a multidimensional 'carbon lock-in'. The creation of the internal combustion engine (ICE) dominant design and the existence of network interdependencies and externalities play as relevant factors of a cumulative process which involves markets, technologies and institutions. But many other scholars refer - both explicitly and implicitly - to lock-in phenomena to explain the past, current and foreseeable evolution of the car regime. John Urry (2008) agrees with Arthur's and Unruh's vision, using similar words:

“The complex system of automobility stems from the path dependent pattern laid down in the 1890s. Once economies and societies were 'locked in' to the 'steel-and-petroleum' car, (...) massive increasing returns resulted for those producing and selling those cars and their associated infrastructure, products and services. Social life came to be locked in to the mode of mobility that automobility both generates and presupposes.” (p. 344)

Inter alia, this implies that mobility behaviour too is locked in to the car: consumers prefer the car also because the built environment (cities and infrastructures) is tailored to the car itself (Sanne, 2002) and they are not able to evaluate the potential benefits of alternatives. The latter consideration has significant impacts on both the modelling of mobility behaviour and the effectiveness of policies aimed at introducing transport innovations. Marco Diana (2010) states very clearly that:

“(...) the mode choice scheme is particularly challenged because we simply cannot collect revealed preferences data from field if the service is not existing (...). An even greater concern can arise when the new service is not well known by potential users because of its technological content, so that usual theoretical assumptions concerning the knowledge of the alternative in the choice set are hardly met and methods such as stated preferences experiments may prove ineffective.” (p. 430)

And this is confirmed by several surveys on the purchase of a new vehicle showing that:

“(...) how consumers improperly assess future savings and discount rates can serve as a powerful impediment to investing in new technologies. (...) [One of these surveys also] “(...) discovered a negative social stigma against more fuel-efficient vehicles, which were consequently resisted by middle and upper classes purchasers who wanted to avoid any association with 'econoboxes'.” (Sovacool and Hirsch, 2009, pp.1098-9)

Such a result is consistent with what was recently stressed by Christen Sanne (2002): the preference for the car is also caused by the embedding of mobility patterns in a more general consumerist culture, which in turn results not only from pervasive marketing, but also from an individualistic ideology.¹⁶ Brown (2001) carries further this approach and suggest that even policy makers are embedded in the ideological context of 'automobility'.¹⁷

The automotive industry is not only acting to lock-in policies, but itself suffers from lock-in. In recent years, the car regime has been able to respond to the societal quest for sustainability demands (and to specific public policies¹⁸); but the even relevant - and largely successful - efforts to both reduce local air pollutants and increase energy efficiency, now seems not sufficient to fulfil the new demanding targets of CO₂ reductions. Orsato and Wells (2007) explicitly argue that a dominant design effect is limiting the ability of the automotive industry to access radically new technologies. Such an argument is further developed by Oltra and Saint Jean (2009) who explain that the hybrid propulsion is chosen not because of its technological and environmental performance, but because of its modularity, that is because - at the same time - it is compatible with the actual core competences, sunk investments and interdependencies of the automotive industry and it is flexible enough to allow the (alternative or sequential) access to many other technological options, including battery and fuel cell vehicles. Moreover, the problem of both fast-charging and hydrogen infrastructures is significantly postponed and reduced. (Avadikyan and Llerena, 2009; van Bree et al., 2010).

A more general conclusion is that different lock-in phenomena mutually reinforce; in particular this applies to innovation policies in the transport sector:

“(...) policy makers define the main objectives and research areas on the basis of the current technology and research directions, while the research proposals, which mainly come from leading automotive firms, are determined by the characteristics of the technological regime and the prevailing trajectories. This tends to create a dynamics in which technologies, institutions and industry structure co-evolve within the dominant technological paradigm.” (Oltra and Saint Jean, 2009, p. 578)

3.4 Looking for a transition

It should now be apparent why the car regime has continued to develop and strengthen in an unsustainable way, despite relevant and persistent policy efforts: both the ability of core actors to resist to change, and the existence of pervasive lock-in phenomena are at the heart of the resilience of the car regime. Many scholars share these considerations and consequently suggest that new policy approaches are needed to make viable radical changes in mobility. With reference to the transport sector, Kemp and Rotmans (2004) proposed to experiment several transport alternatives with the aim of learning about the transition towards a new land-based transport system. Societal deliberation about long-term goals, the establishment of partnerships with new actors

¹⁶ Through a national survey in Japan, Shen et al. (2008) confirmed that the individual environmental consciousness has an influence on transport mode choice.

¹⁷ On a similar topic, see also Heffner et al. (2007).

¹⁸ Such as the European programs CAFE, Auto-Oil I and II.

and the creation of supportive institutions (such as the 'transition arena' and the 'transition council') are crucial elements of the proposed approach. Elzen et al. (2004) analysed two alternative routes for the mobility domain in 2050: 'High-tech individual mobility' (mainly based on new electric vehicles) and 'Customized mobility' (that is, a new transport regime based on the integration of - both new and old - individual and collective transport services). Results are not in term of foreseeable impacts (as is often the case in scenario-based studies), but in term of strategies for transition policies. Other scholars share a similar approach, but with a more explicit use of a backcasting technique as a tool to facilitate higher order learning, that is “a new and radically different way of seeing the problem of individual mobility and of the role of various stakeholder in finding a solution” (Vergragt and Brown, 2007, p. 1106). This approach was simulated in Boston and in Rotterdam, where scenario and long-term visions were proposed and backcasting was developed jointly with stakeholders and public bodies, in order to: ease societal learning, catalyse innovative actors and influence step-by-step policy making (van den Bosch et al., 2005; Vergragt and Brown, 2007). A more quantitative use of transition management is proposed in the EU project 'MATISSE' (Kohler et al., 2009). Here a dynamic model is used to represent transitions and to identify broad policy implications. Simulations confirm the difficulties of pervasive social changes in transport attitudes and behaviour and suggest that - even in the case of simpler technological shifts - continuous and long-lasting support (20-30 years) is needed to establish a stable alternative to the existing gasoline car regime.

All these studies have two relevant points in common. The first one is about the importance of niches, as protected places where the several dimensions of transport innovation can start to align, without being exposed to the competition from the car regime. Several scholars have studied this issue, albeit using different terminologies. Hoogma et al. (2002) pioneered the approach of 'strategic niche management' in the domain of sustainable transport. Many niches were considered, in both the scenarios of 'Electrifying mobility' and 'Reconfiguring mobility'¹⁹, and the following flaws emerged in their management: the insufficient involvement of users, the excessive focus on technological aspects, the predominance of first-order learning, the minimal involvement of outsiders, the absence of an explicit link with sustainability visions. Brown et al. (2004) used a similar approach, studying 'bounded socio-technical experiments' in the domain of personal mobility and focussing mainly on the occurring of higher order learning and the negative impact of incongruent visions and interests among participating actors. Nykvist and Whitmarsh (2008) present empirical evidence and indications of on-going development of niches within the UK and Sweden, with reference to three transition routes: technological change, shift from car use and ownership, and mobility management. Among the results, worth mentioning that: “retaining the diversity of niche development (via incentives, fiscal measures, etc.) and avoiding new lock-ins is again confirmed by our study” (p. 1385). The second common point among these studies on mobility is the consideration of outsiders as a crucial element of transitions. It is argued that the participation of outsiders is crucial to resist pressures to follow conservative paths, coming from actors who are part of the existing regime and have an interest in the status quo (Hoogma et al., 2002; Kemp and Rotmans, 2004). Moreover, outsiders are the main promoter of incremental and radical

¹⁹ These scenarios are similar to those proposed by Elzen et al. (2004); see above.

technological changes of the car regime: relevant innovations in components (such as batteries), vehicles (such as full-electric cars), fuels (such as natural gas) and business models (such as battery-swap schemes) have been developed by actors external to the regime (van Bree et al., 2010); new companies are planning to enter the market with full electric vehicles - the more relevant case is probably BYD²⁰, a Chinese firm whose core competence is not in the production of cars, but in the technology of batteries. Also local and national electric operators are interested in the diffusion of electric vehicles, not only because they already own or manage an essential facility, but also because they aim at the new frontier of 'vehicle-to-grid'; some of them have already started joint commercial programs with dominant automotive companies (Deloitte, 2009). It is apparent that niches and outsiders are interdependent, as outsiders can strengthen and build coalitions more easily if - especially during transitions - they operate in niches.

4. Conclusions

The main thesis of this paper is that a new approach to policy for sustainable transport should be based on evolutionary and institutional theories of change, and especially on one crucial concept that emerged from their recent cross-fertilization: the concept of regime. A regime is a relatively stable assemblage of rules, technologies and markets which fulfils an overall societal function; the regime as a whole - and its structural constituents - are reproduced and changed through agency, that is by individual and collective action and learning. Preferences, discourses, resources and policies, are other essential endogenous components of a regime; strong uncertainty and pervasive path-dependence and lock-in phenomena are the main features of its dynamics.

To understand if the concept of regime may be useful - both as an analytical tool to understand the evolution of transport activities, and as a heuristic for further research on the issue of sustainable transport - a review of the literature on car-based mobility was realized. It was worth it. The concept of regime (or whatever definition is used by scholars) is already widely used in the literature, especially with reference to four relevant domains: 1) The understanding of the early history of the car regime as the result of the co-evolution of cumulative innovations and the ability of 'enactors' to gain an increasing influence on markets and institutions; 2) The role of core actors in the successful effort to establish the gasoline car as a dominant regime. 3) The limiting effect on the future evolution of the car regime (and even more so on the advent of a completely new transport regime) that is generated by multiple and mutually reinforcing lock-in phenomena; 4) The consequent need for a purposeful action to align visions, interests and actions, in order to unlock the car regime.

The concept of regime proved useful as a heuristic tool too. The role of private and public agency is a crucial area that needs further research in order to both envisage and pursue future scenarios of sustainable transport. Inter alia, two issues deserve better understanding: 1) Will the electric car result from the innovative efforts of the automotive industry? Or will it be part of a completely new regime, enacted by managers of electric utilities and producers of batteries? 2) Which public action is

²⁰ BYD stays for 'Build Your Dreams'.

needed to transform the producers of both alternatives to the car²¹ and innovations in the car itself into a coalition enacting a new regime of sustainable transport?

References

- Akerman, J. and Hojer, M. (2006) "How much transport can the climate stand?-Sweden on a sustainable path in 2050", *Energy Policy* 34 (14): 1944-1957.
- Amendola, M. and Gaffard, J.L. (1998) *Out of Equilibrium*; Clarendon Press, Oxford.
- Amendola, M. and Gaffard, J.L. (2006) *The Market Way to Riches: Behind the Myth*, Edward Elgar, Cheltenham and Northampton.
- Arthur, B.W. (1984) "Competing Technologies and Economic Prediction", *Options* 2: 10-13.
- Arthur, B.W. (1999) "Complexity and the Economy", *Science* 284 (1): 107-109.
- Avadikyan, A. and Llerena, P. (2010) "A real options reasoning approach to hybrid vehicle investments", *Technological Forecasting & Social Change* 77 (4): 649-661.
- Banister, D. (2008) "The sustainable mobility paradigm", *Transport Policy* 15 (2): 73-80.
- Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S. and Rickne, A. (2008) "Analyzing the functional dynamics of technological innovation systems: A scheme of analysis", *Research Policy* 37 (3): 407-429.
- Berkhout, F. (2002) "Technological regimes, path dependency and the environment", *Global Environmental Change* 12 (1): 1-4.
- Best, M.B. (1982) "The political economy of socially irrational products", *Cambridge Journal of Economics* 6 (1): 53-64.
- Black (2006) *Internal combustion*, St. Martin'Press, New York.
- Bristow, A.L., Tight, M., Pridmore, A. and May, A.D. (2008) "Developing pathways to low carbon land-based passenger transport in Great Britain by 2050" *Energy Policy* 36 (9): 3427-3435.
- Brown, M.B. (2001) "The Civic Shaping of Technology: California's Electric Vehicle Program", *Science, Technology, & Human Values* 26 (1): 56-81.
- Brown, H.S., Vergragt, P.J., Green, K. and Berchicci, L. (2004) "Bounded socio-technical experiments (BSTEs): higher order learning fir transitions towards sustainable mobility", in: Elzen, B., Geels, F.W. and Green, K. (Eds.) *System innovation and the transition to sustainability*, Edward Elgar, Cheltenham.
- Button, K.J. (2005) "Market and Government Failures in Transportation", in: Button, K.J. and Hensher, D.A. (Eds.) *Handbook of transport strategy, policy and institutions*, Elsevier, Oxford.
- Calef, D. and Goble, R. (2007) "The allure of technology: how France and California promoted electric and hybrid vehicles to reduce air pollution", *Policy Sciences* 40 (1): 1-34.
- Cimoli, M., Dosi, G., Nelson, R. and Stiglitz, J. (2009) "Institutions and Policies Shaping Industrial Development: An Introductory Note", in: Cimoli M., Dosi G., Stiglitz J. (Eds.) *Industrial Policies and Development. The Political Economy of Capabilities Accumulation*, Oxford University Press, Oxford and New York.
- Deloitte (2009) *A new era. Accelerating toward 2020 - An automotive industry transformed*, Deloitte Touche Tohmatsu.
- Diana, M. (2010) "From mode choice to modal diversion: A new behavioural paradigm and an application to the study of the demand for innovative transport services", *Technological Forecasting & Social Change* 77 (3): 429-441.
- Dosi, G. and Grazzi, M. (2010) "On the nature of technologies: knowledge, procedures, artifacts and production inputs", *Cambridge Journal of Economics* 34 (1): 173-184.
- EEA (2008) *Beyond transport policy - exploring and managing the external drivers of transport demand*, EEA Technical Report, No 12/2008, Copenhagen.
- Elzen, B., Geels, F.W., Hofman, P.S. and Green, K. (2004) "Socio-technical scenarios as a tool for transition policy: an example from the traffic and transport domain", in: Elzen, B., Geels, F.W. and Green, K. (Eds.) *System innovation and the transition to sustainability*, Edward Elgar, Cheltenham.

²¹ That is, non-motorized transport, mass transit, shared transport, etc.

- Foxon, T.J., Reed, M.S. and Stringer, L.C. (2009) "Governing Long-Term Social-Ecological Change: What Can the Adaptive Management and Transition Management Approaches Learn from Each Other?", *Environmental Policy and Governance* 19 (1): 3-20.
- Freeman, C. and Soete, L. (1997) *The Economics of Industrial Innovation*, MIT Press, Cambridge (MA).
- Freeman, C. and Louca, F. (2001) *As Time Goes By: From the Industrial Revolutions to the Information Revolutions*, Oxford University Press, Oxford.
- Geels, F.W. (2004) "From sectoral systems of innovation to socio-technical systems. Insights about dynamics and change from sociology and institutional theory", *Research Policy* 33 (6-7): 897-920.
- Geels, F.W. (2005a) *Technological Transitions and System Innovations: A Co-evolutionary and Socio-Technical Analysis*, Edward Elgar, Cheltenham.
- Geels, F.W. (2005b) "The Dynamics of Transitions in Socio-Technical Systems: A Multi-level Analysis of the Transition Pathway from Horse-drawn Carriages to Automobiles (1860-1930)", *Technology Analysis & Strategic Management* 17 (4): 445-476.
- Geels, F.W. and Schot, J. (2007) "Typology of socio-technical transition pathways", *Research Policy* 36 (3): 399-417.
- Genus, A. and Coles, A. (2008) "Rethinking the multi-level perspective of technological transitions", *Research Policy* 37 (9): 1436-1445.
- Giddens, A. (1984) *The Constitution of Society*, Polity Press, Cambridge.
- Goldman, T. and Gorham, R. (2006) "Sustainable urban transport: Four innovative directions", *Technology in Society* 28 (1-2): 261-273.
- Hajer, M. and Laws, D. (2006) "Ordering through Discourse", in: Moran, M., Rein, M. and Goodin, R.E. (Eds.) *The Oxford Handbook of Public Policy*, Oxford University Press, Oxford.
- Heffner, R.R., Kurani, K.S. and Turrentine, T.S. (2007) "Symbolism in California's early market for hybrid electric vehicle", *Transportation Research Part D: Transport and the Environment* 12 (6): 396-413.
- Hickman, R. and Banister, D. (2007) "Looking over the horizon: Transport and reduced CO₂ emissions in the UK by 2030", *Transport Policy* 14 (5): 377-387.
- Hickman, R., Ashiru, O. and Banister, D. (2010) "Transport and climate change: Simulating the options for carbon reduction in London", *Transport Policy* 17 (1): 110-125.
- Hodgson, G.M. (2006) "What Are Institutions?", *Journal of Economic Issues* 40 (1): 1-25.
- Hodgson, G.M. and Knudsen, T. (2006) "Why we need a generalized Darwinism, and why generalized Darwinism is not enough", *Journal of Economic Behavior & Organization* 61 (1): 1-19.
- Holtz, G., Brugnach, M. and Pahl-Wostl, C. (2008) "Specifying 'regime' - A framework for defining and describing regimes in transition research", *Technological Forecasting & Social Change* 75 (5): 623-643.
- Hoogma, R., Kemp, R., Schot, J. and Truffer, B. (2002) *Experimenting for sustainable transport: the approach of strategic niche management*, Spon Press, Oxon.
- Ieromonachou, P., Potter, S. and Warren, J.P. (2007) "A Strategic Niche Analysis of Urban Road Pricing in the UK and Norway", *European Journal of Transport and Infrastructure Research* 7 (1): 15-38.
- Jacobsson, S. and Johnson, A. (2000) "The diffusion of renewable energy technology: an analytical framework and key issues for research", *Energy Policy* 28 (9): 625-640.
- Johansson, B. (2009) "Will restrictions on CO₂ emissions require reductions in transport demand?", *Energy Policy* 37 (8): 3212-3220.
- Kemp, R. (2005) "Zero Emission Vehicle Mandate in California: misguided policy or example of enlightened leadership?", in: Sartorius, C. and Zundel, S. (Eds.) *Time Strategies, Innovation and Environmental Policy*, Edward Elgar, Cheltenham.
- Kemp, R. and Rotmans, J. (2004) "Managing the transition to sustainable mobility", in: Elzen, B., Geels, F.W. and Green, K. (Eds.) *System innovation and the transition to sustainability*. Edward Elgar, Cheltenham.
- Kemp, R., Avelino, F. and Bressers, N. (this Issue) "Transition Management as a Model for Sustainable Mobility", *European Transport/Trasporti Europei* 47.
- Köhler, J. (2006) "Transport and the environment: the need for policy for long-term radical change", *Intelligent Transport Systems* 153 (4): 292-301.
- Köhler, J., Whitmarsh, L., Nykvist, B., Schilperoord, M., Bergman, N. and Haxeltine, A. (2009) "A transitions model for sustainable mobility", *Ecological economics* 68 (12): 2985-2995.
- Leydesdorff, L. and Meyer, M. (2006) "Triple Helix indicators of knowledge-based innovation systems. Introduction to the special issue", *Research Policy* 35 (10): 1441-1449.

- Litman, T. (2005) "Efficient vehicles versus efficient transportation. Comparing transportation energy conservation strategies", *Transport Policy* 12 (2): 121-129.
- Loorbach, D. (2007) *Transition Management: New Mode of Governance for Sustainable Development*, International Books, Utrecht.
- Maggi, S. (2005) *Storia dei trasporti in Italia* (History of transport in Italy), Il Mulino, Bologna.
- Maréchal, K. (2010) *Ecological Economics* 69 (5): 1104-1114.
- Markard, J. and Truffer, B. (2008) "Technological innovation systems and the multi-level perspective: Towards an integrated framework", *Research Policy* 37 (4): 596-615.
- May, A.D., Page, M. and Hull, A. (2008) "Developing a set of decision-support tools for sustainable urban transport in the UK", *Transport Policy* 15 (6): 328-340.
- Meadowcroft, J. (2009) "What about the politics? Sustainable development, transition management, and long term energy transitions", *Policy Science* 42 (4): 232-340.
- Metcalf, J.S. (2010) "Technology and economic theory", *Cambridge Journal of Economics* 34 (1): 153-171.
- McCollum, D. and Yang, C. (2009) "Achieving deep reductions in US transport greenhouse gas emissions: Scenario analysis and policy implications", *Energy Policy* 37 (12): 5580-5596.
- Moriarty, P. and Honnery, D. (2008) "Low-mobility: The future of transport", *Futures* 40 (10): 865-872.
- Nelson, R.R. (2008) "What enables rapid economic progress: What are the needed institutions?", *Research Policy* 37 (1): 1-11.
- Nelson, R.R. and Winter, S.G. (1982) *An Evolutionary Theory of Economic Change*, Harvard University Press, Cambridge (MA) and London.
- Nieuwenhuis, P., Wells, P. and Vergragt, P.J. (2004) "Introduction to the Special Issue on Technological Change and Regulation in the Car Industry", *Greener Management International* 47.
- Nil, J. and Kemp, R. (2009) "Evolutionary approaches for sustainable innovation policies: From niche to paradigm?", *Research Policy* 38 (4): 668-680.
- North, D. (2005) *Understanding the process of economic change*, Princeton University Press, Princeton and Oxford.
- Nykvist, B. and Whitmarsh, L. (2008) "A multi-level analysis of sustainable mobility transitions: Niche development in the UK and Sweden", *Technological Forecasting & Social Change* 75 (9): 1373-1387.
- Oltra, V. and Saint Jean, M. (2009) "Sectoral systems of environmental innovation: An application to the French automotive industry", *Technological Forecasting & Social Change* 76 (4): 567-583.
- Orsato, R.J. and Wells, P. (2007) "U-turn: the rise and demise of the automobile industry", *Journal of Cleaner Production* 15 (11-12): 994-1006.
- Ostrom, E. (2000) "Collective Action and the Evolution of Social Norms", *The Journal of Economic Perspectives* 14 (3): 137-158.
- Paolini, F. (2007) *Storia sociale dell'automobile in Italia* (Social history of the car in Italy), Carocci, Roma.
- Pavitt, K. (1999) *Technology, Management and Systems of Innovation*, Edward Elgar, Cheltenham.
- Perez, C. (2010) "Technological revolutions and techno-economic paradigms", *Cambridge Journal of Economics* 34 (1): 185-202.
- Rammel, C. and van den Bergh, J.C.J.M. (2003) "Evolutionary policies for sustainable development: adaptive flexibility and risk minimising", *Ecological Economics* 47 (2-3): 121-133.
- Rao, H. (2004) "Institutional activism in the early American automobile industry", *Journal of Business Venturing* 19 (3): 359-384.
- Raux, C. (2007) "How should transport emissions be reduced? Potential for emission trading systems", *Discussion Paper*, No. 2008-1, OECD-ITF Joint Transport Research Centre.
- Rietveld, P. and Stough, R.R. (2005) "Institutional dimensions of sustainable transport", in: Rietveld, P. and Stough, R.R. (Eds.) *Barriers to sustainable transport*, Spon Press, Oxon.
- Safarzynska, K. and van den Bergh, J.C.J.M. (2010a) "Demand-supply coevolution with multiple increasing returns: Policy analysis for unlocking and system transitions", *Technological Forecasting & Social Change* 77 (2): 297-317.
- Safarzynska, K. and van den Bergh, J.C.J.M. (2010b) "Evolving power and environmental policy: Explaining institutional change with group selection", *Ecological Economics* 69 (4): 743-752.
- Sanne, C. (2002) "Willing consumers-or locked-in? Policies for a sustainable consumption", *Ecological Economics* 42 (1-2): 273-287.
- Sartorius, C. (2006) "Second-order sustainability-conditions for the development of sustainable innovations in a dynamic environment", *Ecological Economics* 58 (2): 268-286.

- Schot, J., Hoogma, R. and Elzen, B. (1994) "Strategies for shifting technological systems. The case of the automobile system", *Futures* 26 (10): 1060-1076.
- Schot, J. and Geels, F.W. (2007) "Niches in evolutionary theories of technical change. A critical survey of the literature", *Journal of Evolutionary Economics* 17 (5): 605-622.
- Shen, J., Sakata, Y. and Hashimoto, Y. (2008) "Is individual environmental consciousness one of the determinants in transport mode choice?", *Applied Economics* 40 (10): 1229-1239.
- Shove, E. and Walker, G. (2007) "CAUTION! Transitions ahead: politics, practice, and sustainable transition management", *Environment and Planning A* 39 (4): 763-770.
- Silverberg, G., Dosi, G. and Orsenigo, L. (1988) "Innovation, diversity and diffusion: a self-organisation model", *The Economic Journal* 98 (5): 1032-1054.
- Simon, H. A. (1987) *Models of Man*, Garland, New York/London.
- Smith, A., Stirling, A. and Berkhout, B. (2005) "The governance of sustainable socio-technical transitions", *Research Policy* 34 (10): 1491-1510.
- Smith, A. and Kern, F. (2009) "The transition storyline in Dutch environmental policy", *Environmental Politics* 18 (1): 78-98.
- Sovacool, B.K., Hirsh, R.F. (2009) "Beyond batteries: An examination of the benefits and barriers to plug-in hybrid electric vehicles (PHEVs) and a vehicle-to-grid (V2G) transition", *Energy Policy* 37 (3): 1095-1103.
- Stanley, J.K., Hensher, D.A., Loader, C. (2009) "Road transport and climate change: Stepping off the greenhouse gas", *Transportation Research Part A*, doi:10.1016/j.tra.2009.04.005.
- Suurs, R.A.A., Hekkert, M.P., Kieboom, S. and Smits, R.E.H.M. (2010) "Understanding the formative stage of technological innovation system development: The case of natural gas as an automotive fuel", *Energy Policy* 38 (1): 419-431.
- Unruh, G.C. (2000) "Understanding carbon lock-in", *Energy Policy* 28 (12): 817-830.
- Urry, J. (2008) "Governance, flows, and the end of the car system?", *Global Environmental Change* 18 (3): 343-349.
- van Bree, B., Verbong, G.P.J. and Kramer, G.J. (2010) "A multi-level perspective on the introduction of hydrogen and battery-electric vehicles", *Technological Forecasting & Social Change* 77 (4): 529-540.
- van den Bergh, J.C.J.M., van Leeuwen, E.S., Oosterhuis, F.H., Rietveld, P. and Verhoef E.T. (2007) "Social learning by doing in sustainable transport innovations: Ex-post analysis of common factors behind successes and failures", *Research Policy* 36 (2): 247-259.
- van den Bosch, S.J.M., Brezet, J.C. and Vergragt P.J. (2005) "How to kick off system innovation: a Rotterdam case study of the transition to a fuel cell transport system", *Journal of Cleaner Production* 13 (10-11): 1027-1035.
- Vergragt, P.J. and Brown, H.S. (2007) "Sustainable mobility: from technological innovation to societal learning", *Journal of Cleaner Production* 15 (11-12): 1104-1115.
- Vieira, J., Moura, F. and Viegas, J.M. (2007) "Transport policy and environmental impacts: The importance of multi-instrumentality in policy integration", *Transport Policy* 14 (5): 421-432.
- Voß, J.P., Bauknecht, D. and Kemp, R. (Eds.) (2006) *Reflexive governance for sustainable development*. Routledge, Cheltenham.
- Voß, J.P., Smith, A. and Grin, J. (2009) "Designing long-term policy: rethinking transition management", *Policy Science* 42 (4): 275-302.
- Walker, W. (2000) "Entrapment in large technology systems: institutional commitment and power relations", *Research Policy* 29 (7-8): 833-846.
- Witt, U. (2008) "Observational learning, group selection, and societal evolution", *Journal of Institutional Economics* 4 (1): 1-24.
- Zweynert, J. (2009) "Interests versus culture in the theory of institutional change?", *Journal of Institutional Economics* 5 (3): 339-36.