Socio-Technical Scenarios as a tool for Transition Policy

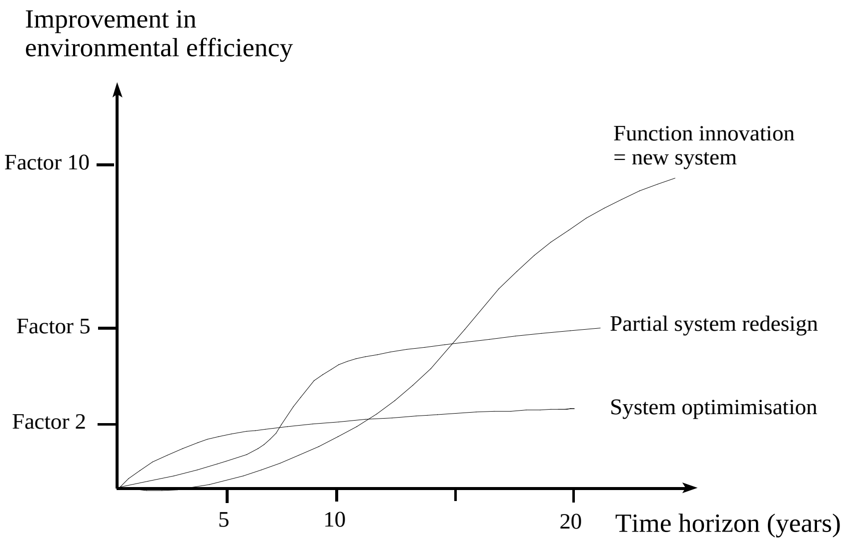
An example from the traffic and transport domain

Boelie Elzen, Frank Geels, Peter Hofman (University of Twente) and Ken Green (UMIST)

Paper for 10th International Conference of the Greening of Industry Network
Gothenburg, Sweden, 23-26 June 2002

1 Introduction

Substantial improvements in environmental efficiency can be achieved via incremental change leading to system optimisation. Much larger gains, however, are possible through system innovation or *technological transitions* (in short, transitions) (see Figure; from Weterings et. al 1997).



Transtions not only involve new technologies but also changes in user practices, legislation, policy, infrastructure, networks, and institutions. In short: transitons imply a combination of technical and social change. While transtions offer large potential to achieve environmental gains, their complexity and uncertainty pose problems for policy makers: which technologies stimulate; and how? To assist policy makers with these questions they need anticipation tools. Traditional technological forecasting methods, however, are not very suited to explore transitions, because they pay virtually no attention to the *interaction* between technology and society. To remedy this shortcoming this paper develops a new tool: Socio-technical scenarios (STSc). STSc are anticipation tools that can assist policy makers to design strategies that take into account the long-term and socio-technical nature of transitions.

We will start this paper by indicating some problems of current and traffic and transport policies, followed by discussing some of the shortcomings of existing foresight methods. Next we will present the STSc method after a brief sketch of the theory it is based upon. We will illustrate the method by presenting two (short) scenarios, the first emphasising technical substitution (as existing methods typically would), the second describing a broader transformation process, including strong societal and behavioural change. In the final section, we will evaluate the usefulness of this method by developing policy recommendations, providing at least a partial answer to the problems that we started with. Thus, we demonstrate the overall promise of the method.

2 Problems of current traffic and transport policy

The traffic and transport system causes major societal problems. Emissions of pollutants from vehicles create health hazards to humans and other living species. CO_2-emissions contribute to global warming. The continuously increasing numbers of vehicles cause congestion, worsen accessibility of many destinations and threaten the liveability of cities and living quarters.

Since the 1960s these problems have been on the agenda of public authorities. Typically, they were split into behavioural and technological problems. Emissions were seen as a technical issue related to the engine technologies and fuels used. Congestion was primarily a behavioural issue caused by people travelling (too) much and/or choosing an inefficient mode of travel.

The split strongly determined the search for solutions. Emissions were primarily the problem of the vehicle industry that was asked or forced through legislation to develop cleaner cars and other vehicles. Congestion was primarily tackled by making an appeal to people’s responsibility to society via awareness campaigns, asking them to travel less or make more use of public transport.

Attempts to reduce congestion have had minimal success. As a result, policy makers as well as many others have become increasingly sceptical towards possibilities to influence people’s travel behaviour. A shift has taken place towards almost exclusively relying on technical solutions to tackle mobility problems. This shift does not remain uncontested, however. A variety of actors, especially public interest groups concerned with the environment and the liveability of cities, continue to emphasise that only a change of behaviour of travellers can lead to fundamental (or sustainable) solutions to traffic and transport problems.

Policy-makers at different levels have used a broad variety of strategies and policy instruments in attempts to tackle the problems indicated. There have been successes (e.g. the drastic reduction of per vehicle emission of pollutants) but in other areas the problems only seem to get worse. Some of the reasons for this lack of success include:

- Problems are typically broken down into small segments and policies are developed to tackle each of these parts individually. In the process, the longer term as well as the interaction between these parts disappears from sight.
- Policy makers face a wide variety of claims on the potential of alternatives. Some claim, for instance, that electric vehicles (EV) are a key option for sustainability. Sceptics, however, argue that EVs have been, are and always will be the technology of the future. Policy makers are not able to assess these different claims.
- In principle, there is a wide variety of policy approaches and instruments that can be chosen from. Only to a very limited extent is the choice of approach and instruments

based on a well-founded analysis. The problem is complicated by the various policy levels (EU, national and local) that play a role.

To tackle these problems, it would be needed to bring a longer term and more integrated perspective into the process of policy making. The typical way of doing this is by means of foresight or scenario methods.

3 Conventional foresight and scenario methods

In the second half of the 20th century, a range of methods has been developed to formalise and structure anticipation efforts, e.g. trend extrapolation and curve fitting, computer modelling, cross impact analysis, Delphi methods, scenarios and foresight exercises. Interest in these approaches has been going up-and-down, partly because each of them had some fundamental problems. These included:

- Too much attention for quantitative, reductionist methods, and a lack of attention to qualitative aspects. (Coates 1989, 17)
- Forecasting methods assumed that the future would be too much be like the past. Forecasts were too much based on extrapolations and the assumption of incremental change. There was too little attention for discontinuity and radical change. (Sapio 1995, 114)
- Forecasting methods focused too narrowly on specific topics, without looking at the broader system. Coates et al. 1994, 24).
- Forecasting methods are based too narrowly on neo-classical economic approaches. Many technology-scenarios assume a set of technologies on the supply side, characterized by generic aspects such as price, performance and a historically calibrated ‘learning curve’. On the demand side, a homogeneous set of consumers is assumed with fixed preferences, sometimes complemented with government regulations as part of the selection environment. The development and diffusion of technologies is assumed to be economically driven: technologies with higher cost/performance ratios win higher market shares. For various reasons, this conceptualization is not wrong, but limited. (Leonard-Barton 1988; Nelson 1994 and 1995; Rosenkopf and Tushman 1994).
- Many technology-scenarios look at (emerging) technologies independently. Technical trajectories are analysed and characterised with learning curves as if they were independent. In reality, however, these trajectories influence each other. Interactions between technologies may be competitive, but also more complementary and symbiotic (Pistorius and Utterback 1997).
- A sixth problem is that scenarios can have a ‘macro-bias’ (Geels 2002). This means that the dynamics and outcomes of the scenarios depend too much on such macro-aspects (e.g. econonomic growth, environmental awareness, oil price). The ‘logic’ of the scenarios is top-down in the sense that processes and actions at the meso- and micro- level are determined by macro-elements. The related problem is that the dynamics and outcomes are unsurprising and somewhat tautological (Schoonenboom & Van Latensteijn, 1997).

To cope with the problems, there are several directions of improvement. The first improvement is to include more qualitative elements in the future explorations, even when this leads to methods that are ‘looser’. (cf. Huss 1988, 378; Simmonds 1989, 67) With regard to technological development this means that attention should not just be given to aggregate variables such as price and performance, but also to aspects like actor strategies, social networks and learning processes.

Secondly, a major direction for improvement is to focus more on radical technological change. A range of analysts identifies this as an important challenge, although they also signal some problems, particularly the lack of appropriate theories. (cf. Amara 1988, 395-396; Ayres 1989, 49)

Thirdly, to explore radical technological changes, a broader systemic viewpoint is needed. The future exploration should not focus on individual technologies, but at the interactions between technologies, e.g. competition, complementary, hybridizations. Furthermore, the exploration should not only look at technologies and markets, but also at possible changes in user preferences, policy, cultural changes, infrastructure. These changes do not occur independently, but in interaction. To analyse and explore the co-evolution of these dimensions, a systemic and socio-technical perspective is needed. (Murdick and Georgoff 1993, 1; Porter et al. 1991, 17-19).

A fourth direction of improvement is to develop a futures methodology, which allows for meso- and micro-dynamics, next to macro-dynamics. The dynamic and outcome of a futures methodology should not only depend on macro-factors, but also on sectoral dynamics, where different actor groups (e.g. firms, users, public authorities, universities) are involved in learning processes and strategic games.

4 Our approach – Socio Technical Scenarios

In this paper we develop a new futures methodology which takes these four directions for improvement into account. We call this methodology sociotechnical scenarios (STSc), and develop it to explore possible routes for technological transitions. To understand and describe technological transitions we use a theory of socio-technical change, which is robust and broad enough to deal with a wide variety of situations (see next section). Thus, STSc are theory-based. In earlier work, we made some preliminary attempts at building STSc (Elzen et al, 1998; Deuten et al, 1998) and articulated the conceptual basis (Geels, 2002).

4.1 Dynamic of socio-technical change

The STSc method is based on what we call the *transition theory*. This theory builds upon insights from the domain of *Science and Technology Studies* (STS) that emphasises the interrelatedness between technical and social change. STS analyses how technology is shaped by social, economic, cultural and political forces as well as how new technologies shapes society and the interaction between various actors.

At the heart of the transition theory are three ‘levels’ and the interactions between them (the *multi-level* perspective; Kemp, Rip and Schot 2001). These levels are:

1. the *socio-technical landscape*: this describes broad processes and factors in society (e.g. cultural developments, climate policy) that affect a wide range of developments;
2. the *socio-technical regime*: a specific sector of society of interest to the analyst (in our case traffic and transport). Regimes describe the interrelation between technology, policy, user preferences, infrastructures, etc.
3. *Technological niches*: ‘alternative’ technologies that hold a promise to play a role in the regime but that cannot compete (yet) with existing technologies. This is partly an economic issue but it also requires tuning of a variety of technical and social factors including infrastructure requirements, user preferences, policy, etc. In niches, learning processes and interactions between actors are key.

Innovation within a socio-technical regime is typically incremental. Under specific circumstances, however, development within the socio-technical landscape and/or in niches can get linked to the regime to induce developments that eventually lead to a drastic reform, i.e. a transition.

4.2 Basic STSc features: patterns and mechanisms

Most innovation takes place within the regime, typically leading to gradual evolution or regime optimisation. This gradual pattern results from a regime consisting of a wide variety of elements, including technical, behavioural, cultural, political that are *interconnected* and, therefore, cannot change easily. If a new opportunity emerges, parts of the regime typically seek to counter the threat.

Although gradual change is the common pattern, there are plenty historical examples of more radical transitions. Analysis of such transitions indicates that technological niches play a crucial role in their early phases. These niches may emerge and develop for two different sets of reasons. The first reason is that there are always people tinkering with novelties in a, from the perspective of existing regimes, arbitrary way. For example, the initial development of the early internal combustion engine in the late 19th century, from the dominant horse-based regime, was nothing serious in terms of satisfying people's transport needs. The second set of reasons comes from pressure on an existing regime. Such a pressure indicates that there are serious problems in a regime which can be either internal to the regime itself (like congestion in the mobility regime) or come from the socio-technical landscape (e.g. the current pressure to curb CO_2 emissions which affects more than just the transport regime).

Given that there are always niches around it will depend upon the developments within these niches and the interaction between these niches and the regime whether they set things in motion that eventually lead to a transition. In such transitions, we can distinguish two general patterns, viz. (1) *technical substitution* and (2) *broad transformation*.

In the substitution route, socio-technical regimes are relatively stable until the wide diffusion of the new technologies. The diffusion and breakthrough of niches into main markets triggers all kinds of wider changes, and may cause established producers to fail (Schumpeter's 'gales of destruction'). On the level of regimes, this route can be described with punctuations between relatively stable socio-technical configurations. An example is the substitution of sailing ships by steam ships.

In the transformation route, much more is at stake than a technical substitution. There may also be changes in user behaviour, cultural change, policy changes, infrastructural change, etc. Furthermore, there are usually multiple technologies involved. The loosening up of the existing regime may create multiple windows of opportunity for novelties and stimulate actors to experiment with many technical options. Often, these novelties do not break through individually but first merge with each other or with parts of the regime. The typical pattern in an ensuing broad transformation is that regime (usually under pressure) first *opens up* and creates room for a wide variety of niches. Some of those may link up to the regime to create niche markets at the fringes of the regime. One or more of these may then start to grow at the expense of the existing regime until they become the new dominant regime. Then the regime tends to close in again, reducing the room for niches. This pattern can be observed in the mobility regime in the early decades of the 20th century. The electric tram and the bicyle played an important role to open up the horse-based regime. At the fringes, three propulsion technologies (electric, steam and internal combustion) were competing as motorised road vehicles. Eventually, internal combustion became dominant and the two other options disappeared from sight.

Under these general, longer term patterns some shorter term patterns and mechanisms can be distinguished. Some examples are:

- regime pressure creating room for niches (see above);
- regime trying to counter the threat of upcoming niches via various improvements; *sailing ship effect* after sailing ships countering the threat of upcoming steam ships;
- niche cumulation: niches building further upon each other like ‘self-service public transport’ developing out of the EV (electric vehicle) niche;
- niche proliferation: niches spreading to other domains (other regimes or geographically);
- hybridisation: the merger of two options (either two niches or a niche with the regime) to create something new, e.g. the merger of the EV and the internal combustion engine car into the hybrid electric vehicle (HEV);
- forking: the opposite from hybridisation, i.e. the split of an option into to different concepts like electric vehicles splitting into rail-based and road-based systems;
- new technical developments triggering new societal developments: a new technical option, for instance, may seize the interest of new user groups or make it easier to pursue certain policies;
- emerging new user patterns: some technologies may induce (initially small) groups of users to change their behaviour and these groups may grow under specific circumstances; this may be triggered by a variety of reasons like creating new opportunities, distinction, cost-performance considerations, etc. In transitions, often a combination of such reasons is at work while different reasons may appeal to different sets of users.

Based on this multi-level perspective we have developed a scenario methodology which we call ‘Socio Technical Scenarios’ (STSc). An STSc is a story that describes possible future developments, making use of the patterns and mechanisms described above.

In principle, everything is possible in an STSc but the developments described have to be plausible in terms of the multi-level theory and the patterns and mechanisms used should be likely to emerge under the given circumstances. Thus an STSc-method can lead to a wide variety of different outcomes, but, more importantly, since the developments have to match the multi-level theory it allows to explore *why* developments lead to certain outcomes. Thus, the method can also be a stepping stone to inform strategies that attempt to realise specific outcomes that are desired.

5 Example: Two STScs for the mobility domain

5.1 Introduction

The two scenarios below are meant mainly to illustrate the main features of the approach and its usefulness. For the sake of brevity we present a shrunk version of ‘full scenarios’ that are about 25 pages long.[1] These longer versions give much more detail on how various developments get linked but the brief versions below should suffice to support the main argument we want to make in this paper.

The main contrast between the two scenarios is that they illustrate the two general patterns of technical transitions described above, notably that of technical substitution and broader transformation.

The scenarios below are written as a ‘history of the future’, i.e. in the past tense. This helps to prevent reactions by the reader that ‘something else might also happen’ (which is always the

[1] Described in an as yet unpublished report.

case) and makes the reader focus on the plausibility of the stories. This latter is, after all, our objective: to make plausible stories, i.e. a story that is might to happen under the given circumstances.

5.2 1990-2000: The Pre-Future - A regime under pressure

At the beginning of the 21st century, the traffic and transport regime was gradually changing. There were two main sets of driving forces for these changes, one linked to an internal regime dynamic, the other related to the broader societal embedding of the regime.

The internal dynamic largely revolved around innovation in connection with cars and other types of vehicles. When the car market became more competitive in the second half of the 20th century, automakers developed new products and accessories to gain new markets. One of the effects was that the range of types of vehicles started to broaden. In the 1960s and 70s, the four-person car (sedan and station wagon) was by far the most common type of passenger vehicle. By the late 1990s, however, the range of vehicles included city-cars, space wagons, sport utility vehicles, etc. Although the all-purpose car was still the most popular vehicle, the notion of using a different type of vehicle for different purposes started to gain ground.

The second set of driving forces was related to a range societal problems (partially) associated with traffic and transport. These included:
- polluting emissions
- CO_2 emissions
- congestion

Because of these problems, a range of policy approaches was developed to try and tackle them. This created room for a variety of new technologies and concepts that were developed and tinkered with in niches. The range included a different propulsion concepts for vehicles (electric, natural gas, hybrid, fuel cells, etc.), stimulation of modal shift, new concepts like chain mobility and intermodality, new ownership concepts like car-sharing, etc.

In theoretical terms, the variation process in industry was leading towards a diversification of vehicle types while the selection environment was also changing, partially because the regime was in trouble (congestion) and partially under influence of the socio-technical landscape that exerted pressure to counter pollution and greenhouse gas emissions. The pressure on the regime created room for development of a variety of niches that tried to link up to the regime.

5.4 Scenario 1: High Tech Individual Mobility

5.4.1 2000-2010: Linking up of niches in a regime under pressure

At the turn of the millenium, public authorities at various levels sought to counter problems of highway congestion, city congestion, local pollution and CO_2 emissions. The main strategies to tackle these problems were regulation (e.g. vehicle emission standards and limited access zones) and financial instruments such as taxing CO_2 emissions and various forms of road pricing. Internally, the regime was somewhat opening up in terms of a diversification of passenger vehicle types.

At the regime level, the ‘pay for use’ and ‘road-pricing’ strategies led to the development of a ‘vehicle identity technology’ (VIT), remote recognition technology at the roadside and automatic pay schemes. Various pricing mechanisms were gradually implemented in the period 2005-2010. By the end of the period the most important were:
- substantial CO_2 tax on fossil fuels;
- kilometre fee related to certified emissions for each vehicle;

- rush-hour fees on various highways (intended to stimulate people to drive at other times of the day);
- pay lanes on highways (people willing to pay could choose a less congested lane).

The levels of the fees were subject to occasional change and influenced by a variety of actors and factors. In general, in terms of marginal cost per km, public transport became increasingly competitive to cars, especially during rush hour and for busy road connections but this hardly affected the behaviour of travellers. Overall, the level of mobility increased but so did congestion and its associated problems. Pricing mechanisms had some effect in spreading congestion peaks on main roads but average congestion remained and especially in cities the problems got worse.

Thus, the regime as a whole hardly changed. At the fringes of the regime, though, there were more noticeable effects. One example was the small electric vehicles niche, known as city EVs (CEVs). At the turn of the century such vehicles could be bought but they were not marketed seriously. This changed when the regime pressure made especially various French cites look for alternative transport means to preserve their medieval centres. They saw CEVs as an attractive option and stimulated their use. An initial niche-market was found among affluent city dwellers who valued their high-tech features and functionality. This market appeared to be large enough to attain economies-of-scale effects, making the prices go down and attract a larger customer base, notably city residents with more average incomes. This emerging market and the international competition made other European automakers follow the French after which the CEV niche-market spread to other cities in Europe.

The regime pressure also stimulated the HEV niche. In the early 2000s, two Japanese HEVs could be bought but they were marketed only lukewarmly. The US automakers had also developed prototypes but did not market them. This changed by 2004 when they tried to renegotiate a mandate by de California authorities to sell a certain number of zero-emission vehicles, part of which could be HEVs. The California authorities stood firm, however, threatening with huge penalties for non-compliance. The automakers gave in and once HEVs were marketed, they became a subject of competition between the automakers to make them as attractive as possible. The European automakers soon followed, fearing that the American and Japanese vehicles would also penetrate European markets. HEVs were initially bought by rather wealthy people but around 2010 there prices had dropped considerably and the general picture was that the double fuel efficiency made an HEV cheaper on a lifetime basis. It was expected that in the future the balance would shift further to the advantage of the HEV.

Summarising, by the end of the period the regime as a whole had hardly changed and was still largely conventional vehicle (CV) based. But some small but very visible niche markets (CEV and HEV) were emerging that might help to tackle at least part of the problems more effectively in the future.

5.4.2 2010-2020: The growth of market niches

By 2010, problems associated with the transport regime seemed to increase rather than decrease. Stronger policies were considered necessary to keep cities liveable and ensure accessibility. These policies became also partly shaped by the advent of the CEV and HEV as (niche-) market products. Economic measures and direct regulation continued to be the most important instruments to tackle the problems. At the landscape level pressure to curb CO_2 emissions became stronger and CO_2 taxes on fossil fuels were further increased which was in part accepted on the basis of the argument that people could also buy fuel-efficient hybrids. Fees within the pay-for-use and pay-for-nuisance philosophies were increased but became differentiated to be lower for the upcoming cleaner vehicles. More specific pressure came from cities that imposed an increasing variety of measures to enhance liveability, including:

- develop and enlarge limited access zones, including zones where only electric driving was allowed;
- increase parking rates and differentiate rates according to various nuisance criteria;
- various forms of preferential treatment for public transport.

As the cost of driving increased, depending upon the emissions of pollutants and CO_2, the vehicle industry continued its competition inspired development strategy of making them more fuel-efficient and cleaner. The overall number of vehicles in the Netherlands continued to grow, especially due to the popularity of CEVs which were much cheaper to use and allowed in areas where other vehicles were not allowed. They were mostly bought as the second or third vehicle in the household. The share of hybrids grew considerably, largely because their lifetime cost gradually became lower than for conventional vehicles due to economies of scale and fuel cost savings. Most people, however, continued to prefer the CV since it was more sporty and more responsive to pushing the accelerator. The CV was driven fewer kilometres, though, since many city residents also owned a CEV which they used to drive about the city. Because of the considerable market share of fuel-efficient vehicles and the decreased use of CVs, the CO_2 emissions from passenger transport dropped significantly, somewhere around 20%.

With increasing congestion problems, especially in cities, public authorities at national as well as local levels sought to encourage use of public transport. Congestion and a variety of measures to prioritise public transport (dedicated lanes; traffic priority) had the effect that in urban areas public transport was usually much quicker than driving a vehicle while it was also cheaper due to the increased cost of owning and using cars.

From the perspective of the traveller, the regime had somewhat changed in this period. This was not related to the range of vehicles that could be bought, which still were basically CVs, HEVs and CEVs. What had changed noticeably, though, was the balance in terms of functionality and cost. The numbers and size of areas where CEVs or any motorised vehicle were not allowed was increasing. The overall cost of mobility had increased significantly, except for public transport. This was not so much due to fuel cost, despite a 35% CO_2 tax, as this was largely offset by increased fuel-efficiency, especially for HEVs. The most significant cost items were kilometre fees and parking fees following the pay-for-nuisance philosophy. Still, the vast majority preferred sitting in their ‘private space’ than to ride a busy bus, tram or subway. Although there was increasing variation due to local circumstances, the overall share of public transport did not change significantly compared to the preceding period.

At the fringes of the regime some interesting new developments took place concerning fuel cell buses (FCBs), biofuels and a transformation of the CEV-niche. Concerning FCBs, a lot of development work had been done on fuel cells in the early 2000s but due to a lacking refuel infrastructure and de high cost of fuel cells they were used only used in demonstration projects. By the mid 2010s, however, fuel cells and hydrogen as a fuel received more-and-more attention at the level of the socio-technical landscape for stationary purposes. Under pressure from the need to curb CO_2 emissions the EU and various national governments decided to break the deadlock for development towards a ‘hydrogen fuel economy’ and in the period 2010-2015 made funds available for market introduction projects and fuel outlets at bus depots. Thus the market for FCBs could gradually develop, also making the cost of these vehicles go down due to economies of scale. By 2020, a significant of new buses were FCBs although their total share was still small due to the long depreciation period for buses. Still, it was evident that most bus-riders very much liked FCBs, especially because they were so silent. Due to the public's reaction bus companies increasingly started to believe that an FCB fleet would probably increase ridership and many announced they would only buy FCBs in the future.

The increased regime pressure also provided an impetus for the biofuels niche. Already in the 1990s, biofuels were seen as a potential route to a low CO_2 emission fuel chain. After 2005, discussions in Europe on the need to reduce CO_2 emissions intensified. With the prospect of a drastically reduced fuel consumption per vehicle (due to HEVs) increasing numbers of national and EU policy makers became convinced that biofuels could supply a substantial portion of fuel needs in the longer term and stimulated their introduction. As of 2010, biofuels started making significant contribution and become more widely available, initially by mixing them with conventional fuels.

The regime pressure not only affected market-shares of different options but it also induced some qualitative changes. Concerning CEVs, a new type of user pattern emerged. Initially a CEV was typically the second car next to a CV but some owners sold their first car since they used it too little, making the cost too high. This was especially the case for people who parked in public space because of increasing parking rates for CVs while parking for CEVs was becoming cheaper. These people started using different options to satisfy their longer trips, including train and rental car.

5.4.3 2020-2035: Dominance of the HEV

Although CO_2 emissions from transport had dropped some 20% since the turn of the century, this still came no way near the 80-90 % reduction that was considered necessary to achieve sustainability. HEVs were two times or more fuel efficient than CVs but their market-share was still a minority. An interesting prospect, therefore, was to stimulate a drastic expansion of the HEV-share. In the early 2020s a long term plan was made to double fuel-prices in a decade. For most drivers, this would hardly cost them extra if they moved from CV to HEV but a 10-year period would be needed to allow a smooth transition.

Internal regime pressure also persisted due to the elusive problem of congestion. In the period 2000 - 2020 the overall number of cars and vehicle kilometres travelled in the Netherlands had increased substantially. On highways, various forms of pay-for-nuisance had spread traffic jams rather than decrease them. Within urban areas, parts of cities had been made more pleasant by limited access zones but at the same time congestion in other parts and on main arteries had increased. Even though public transport was virtually always cheaper in terms of direct driving costs, people continued to prefer private means of transport.

In cities, the experience was that citizens highly valued the pedestrian and limited access zones. But people did want these to be accessible by car and public authorities accommodated these desires by limiting the size of these areas and creating parking facilities at the edges. Still, because of the high congestion rates, they continued to use pricing mechanisms to encourage modal shifts and prioritise public transport in various ways. The rates for using private cars in the busiest parts were increased drastically, sometimes doubled. The result was that driving one's own car became several times as expensive as taking public transport, making increasing numbers of people use the latter when going into the city. But this was only the case for these busiest parts with the highest rates and for the rest most people preferred their own vehicle over a bus or tram.

Concerning vehicle types, the share of HEVs more than doubled to get the majority share due to the high CO_2 tax. By the late 2020s this also led to the development of a new vehicle type, the LPG-HEV. LPG conversion of CVs had been common in the Netherlands for decades due to lower taxes. Initially, this was not an interesting option for HEVs as their high fuel efficiency already made them very cheap in fuel cost. But with fuel taxes going up the difference did become significant and the Dutch LPG conversion industry also started to convert hybrids to LPG. The automakers looked at this with interest but saw LPG as typically Dutch. They did catch the trend, however, and started to make gaseous fuel hybrids themselves that could drive on methane (natural gas) that was more widely available across Europe. An interesting additional potential link-up was that methane was increasingly produced from organic sources. In the 2020s they offered gaseous HEVs that were initially sold in small niches since a natural gas infrastructure was not commonly available across Europe.

This created the prospect that fuel stations would have to provide an ever increasing range of fuels which triggered increasing protests from fuel providers. After several years of discussion between automakers, fuel providers and public authorities a voluntary agreement was reached to phase out liquid fuels in the next 1-2 decades and stimulate the use of gaseous fuels. This meant an enormous impetus for the HEV and especially the gaseous version. By 2035, CVs became a small minority of the annual sales market and as a result the CO_2 emissions from passenger transport could decrease further to about half the 2000 level.

Looking for new market opportunities the automakers sought for a vehicle that could not be easily made by small companies as was the case with the CEV. They found this in the concept of the ‘Long Distance Vehicle’ (LDV). They hooked on to the pattern that by 2020 more than 10% of all vehicles were CEVs. Many of these people combined owning a CEV with a conventional vehicle and an LDV might be an interesting substitute for the latter as the cost of driving and owning a CV went up. Fuel cells were expected to be ideal as an LDV. The auto industry had gained some experience with this technology in the preceding decades and, furthermore, fuel cells were commercially produced in increasing numbers for buses. On the basis of this development, pressure was also increasing for a public hydrogen refuel infrastructure. Through a cross-linking of niches, FC-LDVs could help to speed up this process as well as profit from it. In the early 2020s, the first FC-LDVs were introduced to the market. Most vehicles had a petrol reformer and could therefore tank at existing fuel-stations. It’s high tech image indeed appealed to customers and once they had experience with it they appreciated its smooth and silent driving. Initially it was popular among business managers but gradually it became more widely used by a variety of people that drove a lot, e.g. sales representatives. When limited access zones grew in numbers and size it also became common as a taxi. As a result, its market share grew to 10% in 2035.

The persisting congestion problem created new possibilities for an old niche. Since the turn of the century, it had been mainly tackled using various pricing mechanisms. This indeed spread congestion peaks but due to the overall growth of traffic, freight traffic growing even faster than passenger traffic, the overall effect by the 2030s was that various stretches of road were congested virtually 24 hour per day, 7 days per week. Some new highways, tunnels and bridges were constructed during the period 2000-2030 but, after initial relief, the old problems soon re-emerged.

Already in the 1990s, automatic vehicle guidance (AVG) was promoted as a means to increase the capacity of highways drastically, at the same time improving traffic flow and reducing congestion. Since about 2010, the AVG community had been conveying the message that the technology was ready but until the mid-2030s implementation in practice appeared very problematic. One reason was that it would require enormous investments to have any effect and these sources of funding could not be found.

In the mid-2030s, a new linking-opportunity for the niche emerged. The government income from transport (CO_2 and other fuel taxes, pay-for-use and pay-for-nuisance fees, parking fees) was enormous. The ICT industry, that was facing a downturn after several decades of growth, mobilised the auto lobby to stress that car-drivers' taxes were not used to relief congestion while there was a perfect opportunity to do so via AVG. This campaign was successful and by the mid-1930s a national 'Deltaplan traffic flow' was developed that aimed 'boosting' traffic flow in the next 1-2 decades, partially by introducing AVG.

5.4.4 2035-2050: Further technical improvement

Around 2035, CO_2 emissions in the transport regime were reduced to about half the level of the year 2000. To attain the desired 80-90% reduction, however, at least a further reduction of 60% of the remaining half would be necessary. With the increased share of renewable fuels (methane from organic sources; sustainably produced hydrogen), and increasing shares of fuel efficient vehicles (esp. gaseous HEVs) the trend was in the right direction, though. The general belief was that it would suffice to adhere stringently to the CO_2 taxes, maybe increase them a bit further, to achieve the overall reduction goal.

Congestion, however, continued to be an elusive problem. Drastically increasing the cost of owning and driving cars in cities had led to some modal shift but the overall level of congestion, except in limited access areas, was comparable to the situation at the turn of the century. More stringent methods like banning cars further, however, were unacceptable. The problem seemed insoluble.

Highway congestion was attacked vigorously, though, via the "deltaplan traffic flow" and the associated automatic vehicle guidance facilities. The first AVG stretches on highways became available around 2040 and in the following decade the major part of the highway system was equipped with 'smart AVG lanes'. As this development was European wide the auto-industry supplied the vehicles suited for AVG. Using AVG lanes was expensive leading to business traffic as first users for whom the economic benefits of saving time far exceeded the extra driving cost. Also, the affluent users of FC-LDVs and high-end HEVs bought AVG equipped vehicles. By the late 2040s, AVG started to have a significant impact. About half of the highway system, especially in and near urban areas, allowed a choice between self-drive or AVG modes, some 25% of the traffic using the latter. This percentage had grown rapidly in the early 2040s but remained more or less constant in the later years. An important reason was that traffic on the self-drive lanes had been reduced by 25% thus making traffic more smooth and swift there as well. The relative advantage of AVG-lanes thus decreased making especially private citizens not prepared to pay a lot extra for using them.

One of the effects of reduced congestion was that the total number of vehicles started to grow again. Many of the 'extra' vehicles were FC-LDVs. Their share had grown slightly in the period 2035-2045 but increased rapidly later when AVG-lanes became more widely available. The 'AVG-feeling' of smooth driving was congruent with the driving sensation in such a vehicle. By 2050, the market share of this vehicle became 20%. The market of CEVs remained more or less stable while the remainder were HEVs, the vast majority of the latter using gaseous fuel.

FC-LDVs used hydrogen, most of which was sustainably produced, like the electricity for CEVs. Most of the HEVs used gas a considerable portion of which was produced sustainably from biofuels. With the average fuel efficiency of HEVs between 2-3 times that of the average year 2000 CV the overall effect was that the desired CO_2 reduction of 80-90% could be achieved.

5.5 Scenario 2: Customised mobility

5.5.1 2000-2010: Opening up of a regime under pressure

The largest driver in the traffic and transport domain was the elusive problem of congestion. At the turn of the milennium the approach was to tackle this mainly by increasing the capacity of existing infrastructures, either by technical measures that would allow a larger number of vehicles per stretch of road or by pricing measures that would spread traffic peaks across the day. Many cities worried about liveability which was not just a matter of lowering pollution but also of abating noise and making cities more pleasant and safe. The concept of the sustainable city gained popularity and zoning measures (low-speed zones, limited access zones, pedestrian zones) were one of several approaches to try and achieve it. At the landscape level, the concern about CO_2 emissions put pressure on the regime. Formally, this was a concern for the European and national authorities but many local actors were also inspired by it under the adage “think globally, act locally”.

During the period, the private car remained the dominant mode of transport. Overall pkt (passenger kilometres travelled) continued to increase which also increased congestion further. Some bottlenecks were removed by building new bridges, tunnels and (limited stretches of) roads which gave some, albeit often only temporary, relief. Pursuing the approach started at the turn of the century, road pricing became common after 2005. These systems became more and more refined in that the rates were made dependent upon the stretch of road used, time of day, characteristics (emissions, weight) of vehicle used, etc. The overall effect was that by 2010 highway congestion indeed went down but that the underlying road network was used much more intensely.

Although highway congestion went down, congestion in cities continued to get worse. The main instruments to discourage car-use were high parking rates which achieved a very modest intra-urban modal shift, especially in cases where congestion had become so bad that public transport was considerably faster.

Concerning CO_2 emissions it became clear by 2005 that various measures taken had no effect. Taxes on fossil fuels were raised by 20% at the end of the decade but, as had been the experience in previous decades, this hardly affected pkt. It did have an effect on the automakers’ strategies, though. The high pump prices combined with emission related road-use fees, implied that a clean and fuel efficient vehicle could be of the order of € 100-200 per month cheaper than an average vehicle. This gave a serious impetus for the demand for cleaner and more fuel efficient vehicles. As of 2008, some automakers responded to this by also marketing HEVs more seriously and by 2010 they had a small market share.

In cities, congestion continued to increase and local authorities more-and-more got fed up with the traffic situation and sought stronger measures to stimulate alternative means of transport. Measures taken included high cost of car use, zoning measures, improved public transport services, prioritising public transport. By 2010, the effects became noticeable in that considerable modal shifts took place in major cities on intra-urban transport. In many cases, public transport had become a cheaper as well as quicker alternative to car-use.

The pressure on the regime stimulated the growth of various niches. One of these were City EVs (CEVs). In the mid-2000s the French automakers continued the emerging trend of diversification of vehicle types by producing such in substantial numbers for what they saw as a growing market of affluent city-dwellers that wanted to move about easily in French cities with medieval centres. In the period 2005-2010 tens of thousands of CEVs were produced for this niche-market and sold. They were bought mainly as a second vehicle and as a high tech gadget but they were also functional because accompanying measures in various cities (permitted in limited access zones, low parking rates) made it easier to move about in congested cities. When the CEVs became available after 2005, a variety of cities across Europe started to use them in self-service experiments in connection with train rides.

The regime pressure to curb CO_2 emissions also provided opportunities for the biofuels niche. Backed by the EU, national authorities imposed low taxes on biofuels while taxes on fossil fuels went up to stimulate reduction of CO_2 emissions. The established fuel producers liaised with the agro-industry and various processors of organic waste to ensure they would produce the fuels and mixed them with fossil fuels. By 2010, the biofuels share was a few percent but it was growing.

Concerning overall travel behaviour, in 2010 the majority of citizens did not take a much different attitude from the beginning of the decade. A growing group, however, was aware that there was an increasing tension between their role as traveller, wanting ‘right of way’, and their role as city resident, wanting less traffic. In the national statistics, these changes were hardly significant but it became clear that a ‘third group’ of travellers was emerging.

5.5.2 2010-2020: The take-off of intermodal approaches

Emission of pollutants had been brought back considerably (basically because gross-emitters had virtually disappeared) but within cities they were still considered a source of nuisance, mostly because the attitude of city residents was changing: people developed higher standards for ‘quality of city life’. To realise sustainable cities, various city authorities tried push back the role of the car and create alternatives instead. They were supported by the national authorities that used the increasing revenues form fossil fuel taxes and road pricing to support experiments with such alternatives and to implement new schemes that had proven their value. Cities also used increasing parking revenues to support their efforts. At the national level, the general ‘pay for nuisance’ approach was continued in order to spread (and possibly reduce) travel demand and to stimulate people to choose alternative modes of transport. The CO_2 tax on fuels was further increased to stimulate further penetration of biofuels and to encourage people to buy, and thus encourage industry to develop and produce, more fuel-efficient vehicles.

Around 2010, some of the automakers started to mass-market HEVs (see previous period). By 2015, especially due to lower road-use fees and higher fuel efficiency the overall exploitation cost of an HEV was considerably lower than for a conventional vehicle. This made the demand for HEVs rise sharply and it quickly became a subject of fierce competition between the automakers. In the second half of the 2010s, sales-numbers of new HEVs overtook those of conventional cars.

As a niche market, the share of CEVs grew considerably in the 2010s. With increasing numbers and strength of measures to discourage or forbid the use of conventional vehicles in parts of the city, CEVs were a good alternative for a growing group of users. Many city dwellers bought a CEV as a second car and used their conventional vehicle (or, increasingly, their HEV) only for long-distance trips.

The regime pressure for clean vehicles also increased the possibility for fuel cell vehicles. The initial focus was on heavy duty vehicles, especially buses, since the cost of the fuel cell was a smaller fraction of total vehicle and service cost (including driver wages) and because refuelling would be less of a problem since these vehicles were typically refuelled at a central depot. As of 2005, an increasing number of prototypes of such buses was put on trial in various cities across the world. When biofuels became a serious market niche around 2010, some experiments started with buses running on hydrogen produced from organic feedstocks. Because of the low tax on biofuels, such schemes were close to being competitive, close enough to stimulate a substantial increase in demand. Thus, a spiral developed in which increased numbers of fuel cell buses made the price go down which further increased demand, etc. As a result, most of the new buses bought in the second half of the 2010s ran on fuel cells.

With increased congestion and increased cost of driving, public transport became attractive for a growing group of travellers. As a result, the share of long-distance public transport started to grow slowly. Train services were improved and became more frequent. Increased train-use also increased the need to provide good facilities to continue the trip to and from the station. This stimulated city authorities in their quest for the sustainable city and their efforts to improve public transport services and discourage car-use. In a growing number of cities, passengers arriving from elsewhere (either by train or private car) could choose from a variety of options to continue their trip. Their personal assistant (mobile internet link) gave them dynamic info on their options and how to use them. Around 2020, public transport in many cities was considerably quicker than using a private car. In most cases it was also cheaper than the marginal cost of private car use in most cases.

Cities became a focus of attention in connection with transport planning, policy and experimentation. Across Europe, a wave of projects was realised in the 2010s, using or combining a wide variety of options, including:

- A range of (public) transport services, such as:
  - individual public transport (mostly CEVs but also energy efficient small conventional vehicles that industry developed as a potential alternative to CEV)
  - on-demand services (first conventional vans but increasingly hybrid vans when they became available (cf. following section on regime level))
  - direct shuttle services from transfer points to ‘concentrated’ destinations like hospitals, shopping centres, business centres, etc.
- Priority for public transport (dedicated bus lanes; priority signalling)
- Zoning policies
  - barriers between neighbouring zones to make through traffic impossible
  - zero-emission zones
  - no-car zones
- High parking rates (lower for (C)EVs, HEVs and shared-cars)
- Transfer points with a variety of transport services and vehicles to rent.

Experiences in these projects were mixed, depending upon how exactly they were organised and various aspects of the city in question and its residents. Many of these experiments had a strong local flavour but there was a lot of exchange of experience between cities. Gradually a general concept developed characterised by a layered structure of transfer points. At the city level, there were so-called *city mobility stations* (CMS) which linked intra and inter urban traffic. Traditional long-distance train stations were one example but they also developed around P+R facilities (or ’transferiums’, in Dutch) in other locations at the city’s periphery. One level lower, distributed across the city, there emerged *mobility centres* (MC) which linked a variety of high-speed urban transport networks and services with diffuse streams to and from nearby specific destinations. Some car-sharing organisations established their depots at these MCs. This layered structure became known as the City Transfer System (Citrans).

Around 2020, Citrans became generally accepted as the conceptual way to think about sustainable transport in cities. As a complete system, it hardly existed anywhere yet. Various cities had realised bits and pieces that fitted the concept but in general the car was still the dominant means of transport in all but a few European cities. But the broad acceptance of the concept did create a focus in attempts to tackle transport challenges in the future.

Concerning travel behaviour, the ‘third route’ that had started small in the 2010s was becoming a serious way to look at mobility: increasing numbers of citizens started to look in a more functional way at options to satisfy their travel needs and choose the optimal way to satisfy their need depending upon the situation. By 2020, the majority of city residents no longer saw the car as the automatic choice and this became increasingly the case for others as well. Transportation became a more practical need and the proper choice could make a substantial difference in terms of cost, ease of use as well as travel time. In many cases, public transport had the advantage on all dimensions, at least for part of the trip.

5.5.3 2020-2035: Citrans Challenges car Dominance

At the regime level, the wider societal and political pressure to curb CO_2 emissions continued to increase in the period 2020-2035. While there were hopeful signs in the transport sector (increasing contribution of biofuels; increased popularity of very fuel-efficient hybrids) there remained a strong need to curb emissions further and pricing measures would have to achieve this. Congestion problems on main roads had slightly increased but since there were good alternatives this was increasingly seen as a private problem. If people preferred to sit in their own car in a traffic jam it was due to their own choice. City congestion, by contrast, became the prime public issue in connection with mobility. The quest for the sustainable city had only become stronger in the 2010s and, in accordance with it, the pressure increased to reduce the role of the car.

An increasing number of city traffic planners started to see the Citrans concept with multi-modal links as the way to think about transport in a sustainable city. Attempting to realise such schemes, most cities initially focussed on city-level transfer points, usually near a major train station (city mobility station: CMS). Depending upon the local situation, a selection or combination of a range of services was offered, such as long distance trains, bus, metro, tram, shuttle services, ‘individual public transport’ (CEVs offered for short-term rent), long distance rental cars, bicycles.

Interestingly, some of these new combinations, combined with other events, led to significant changes in travel behaviour of various groups. Some people sold their regular car and just kept a CEV for their local trips. For their occasional need of a longer distance vehicle they rented one at the CMS. Although these were seen as a bit strange by the majority the trend did reinforce because there was a sound financial rationale for it. It was just very expensive to own a conventional car that was used for 10,000 km per year or less. The CMS offered a very functional alternative that was also highly flexible. Although these groups were initially small, they did suggest a potential of radical changes eventually.

The most enthusiastic cities concerning Citrans also tried to experiment with and develop neighbourhood level transfer points (mobility centres - MC). At these centres, the same services (although initially on a smaller scale) were offered as at the CMS except for the long-distance trains. The forerunners became widely recognised as good practice examples by policy makers as well as the general public (who learned about them via TV programs). As of 2030, an increasing number of cities started to realise (aspects of) it.

Around 2020 the large majority of new cars sold were HEVs. But even if all cars would be HEVs this would not realise the necessary reduction of CO_2 emissions. Further stimulation of biofuels would make the reduction increase a bit further but this would not suffice to reach the target. This translated into new interest in fuel cell cars running on sustainably produced hydrogen. Public authorities in different countries supported the build up of a refuel infrastructure. Automakers saw this as a new long-term business opportunity, initially for the high-end of the vehicle market.

During the period, the privately owned car kept its dominant position in terms of pkt but its dominance started to become smaller. Concerning HEVs, a further diversification took place which included hybrids running on gaseous fuels. this included hybrids with gas turbines which were very fuel efficient and clean but also rather expensive. Also fuel cell vehicles came up as a market. As occasional renting became more common, many took the opportunity to try out these ‘futuristic’ vehicles which very much stimulated interest in them.

Through taxing measures it became more interesting to use biofuels to produce hydrogen than to mix them with conventional fuels. This made the prices of liquid fuels at the pump go up which made larger numbers of people aware of the increasing cost of self-driving a hybrid which stimulated the ongoing transformation process of taking alternatives more seriously, including doing away with the privately owned all-purpose HEV.

The upcoming and development of transfer points like CMS and MC with a variety of services in many cities redefined the role of public transport. In cities where it had been realised, which were still a minority, except for a small number of ‘car-addicts’, the public transport service system was the way to move about in the city. This system offered far more flexibility and ease of use than the private car, making it attractive for an increasing number of people to do away with the latter. It became common that people used a combination of services tuned to their needs in a specific case, sometimes or part of the trip using a privately owned vehicle, in other cases or for other parts using a service offered by others which might either imply being driven or self-drive.

5.5.4 2035-2050: Citrans Victory - Demise of the Private Car

By 2035, based on the good practice examples from the previous period, local authorities across Europe had become convinced that the Citrans system was key to shape transport in the sustainable city. They were determined to realise such a system by a combination of infrastructural planning and a variety of measures to stimulate its use and discourage the possession and use of private cars.

National level authorities, joining forces at the EU level, saw it as their task to induce further reduction of the use of fossil based fuels, partially by stimulating the wide use of the gas-turbine HEV. In 2035 they announced that the tax reduction of liquid fuels mixed with biofuels would be gradually abandoned in the period 2038-2045 while such a reduction would not apply to gaseous fuels. As a result, by 2045 the fuel cost for an HEV running on liquid fuel could be three times as high as for gaseous (in case of pure biogas) fuel.

In cities across Europe, developing a local variant of the Citrans concept was at the centre of attention in the period 2035-2050. Cities tried to stimulate its development by developing a mix of prohibitions, fees and taxes that worked best locally. Attempts were also made to enthuse the public by TV programs on good practice examples. The public was sensitive to this for a variety of reasons: they very much liked living in low-car-use neighbourhoods; the Citrans system offered good and flexible mobility while using the private car was slow and very expensive.

As a result, Citrans made its way across Europe. This was not only a matter of technical change but travellers, policy-makers, transport operators as well as industry started to think in a new way about mobility and transport. Policy makers evaluated new problems and options in terms of how they could improve the Citrans concept, i.e. make it more convenient to use and further discourage private car use. For travellers, using a combination of modes was self-evident and for any trip one started to check the mobility information system that provided a variety of options that the traveller could then choose from on the basis of felt needs and preferences.

As a result, private car ownership and use went down rapidly in the period 2035-2050. At the same time, a clear shift in the type of car used also took place, largely due to the (dis-) incentive structure of fuel taxes and road-use fees. These were much lower for the clean fuels and cars running on sustainably produced hydrogen (FCEV) and methane (gas turbine HEV). The effect was that by 2050 virtually all new cars were either FCEVs or gas-turbine hybrids which implied that by 2060, when most HEVs running on liquid fuels would be taken out of use, the use of fossil based fuels would come to an end, thus symbolising the demise of the old regime.

6 Reflection upon the scenarios

The two scenarios are substantially different. Let us make a closer comparison as this can provide stepping stones for developing policy recommendations.

The first decade of the two scenarios does not differ very much. ICE cars keep dominating, a CEV niche catches a limited market share and HEVs are coming up. In the first scenario, HEVs appear a bit sooner due to a local firm attitude by the California authorities. Once they are offered, though, in both scenarios the market for HEV can grow rather fast under the regime pressure to curb CO_2 emissions which is translated into high fuel prices. The high fuel efficiency of the HEV then makes it an attractive option for a growing customer base.

At the fringes, however, there are some noticeable differences between the two scenarios. In contrast to the first, city authorities in the second scenario are much more pro-active, trying to give at least parts of cities a sustainable flavour and tinkering with al kinds of options for more functional, clean and less intrusive mobility.

The difference in niche-developments in the first episode between the two scenarios sets the stage for very different developments in later episodes. The first scenario continues to resemble the present situation with an emphasis on car-ownership and car-use to satisfy mobility needs. Where the nuisance of car-use gets too large, attempts are made to tackle each problem separately, leading to a variety of technological measures to tamper the negative externalities of car dominance. This leads to a much wider variety in mobility options than as present and on average a drastic increase in fuel efficiency. As a result, CO_2 emissions from passenger transport can be brought back by 80% compared to the turn of the millenium. In the second scenario, there is much more tinkering, new types of mobility patterns emerging at the fringes are taken seriously and stimulated to grow slowly, various options are combined to explore new forms of chain mobility, etc. The end result compared to the first scenario is that car-ownership goes down drastically and that people use a variety of mobility services, either provided publicly or by a private operator. Many own a CEV to move about the city but only a small minority owns a car to cover longer, inter-urban distances. This has a much larger effect on net CO_2 emissions that can be brought down to virtually zero.

What makes the second scenario different is a willingness and even determination to experiment with novelties. Especially cities play an active role in the search for alternative solutions, also trying to learn from experiences elsewhere. Explicit attempts are made to look at and develop new systems rather than individual technologies.

In both scenarios, economic instruments and regulation also play an important role but they do so in a different way. In the first scenario, economic instruments are often used in a situation where most people, like in the present, feel they have no alternative but to keep driving and pay the increased cost. The main effect of turning up the pressure is that it stimulates industry to develop new technologies that may take away part of the pressure. Thus the overall result becomes a high-tech variant of the present system. In the second scenario, however, economic measures and regulation kick in at a point where new alternatives have been articulated in niches and have also gained some visibility for the general public. These measures are thus combined with a strategy of probing and learning, eventually leading to a drastic transformation of the mobility system.

7 Policy recommendations

At the start of this paper we indicated several problems of current policies to tackle transport problems, notably:

- breaking problems into small parts and attempting to solve these separately;
- difficulty to assess the potential of a range of alternatives in niches;
- choosing the appropriate instruments to reach desired effects and tune policies between different levels.

In this section, we will use the scenario exploration above to make suggestions on how to deal with these problems. To create more room for a variety of niches, which is crucial to induce a transformation, it helps to put pressure on the regime. This will be discussed in the following section. Next, we will present some recommendations concerning learning in niches.

7.1 Put pressure on the regime

Current policies largely rely on direct regulation and economic measures to tackle transportation problems. The scenarios illustrate that this is not so much wrong as it effectively puts pressure on the regime but such measures need to be better tuned and combined with other measures.

Both scenarios feature economic instruments to curb CO_2 emissions and to stimulate car-drivers to change their behaviour in order to fight congestion. Concretely, the measures include:

- increased fuel taxes for fossil based fuels, more than doubling in a couple of decades;
- differential road pricing schemes taking into account various types of nuisance (after the development of automatic vehicle recognition technology);
- high parking rates.

In both scenarios, this stimulates the use of HEVs although via a somewhat different path. Indeed, HEVs could be a key technology to reduce CO_2 emissions along with pollutants. as demonstrated vehicles show the fuel efficiency of an HEV can be a factor of 2 better than for a conventional car. Also, an HEV offers the possibility of driving in zero-emission mode in places where pollutants hurt most. Furthermore, the scenarios illustrate that an HEV may provide a stepping stone towards a gaseous fueled hybrid with potential further advantages.

Developing a market for HEV basically seems to be a matter of getting over a threshold. Once over the threshold, both scenarios illustrate that the market can grow rapidly which could be speeded up via pricing policies. How to overcome the threshold, then? In the first scenario, the process is more or less forced through the California authorities and then proliferates due to the automakers competing globally. In the second scenario, the political will to increase fuel prices convinces automakers that there will be a market for hybrids. Thus the issue seems to be to either force or convince the automakers. In the European context, the first route does not fit the political culture and therefore it is recommended that European countries make clear to the automakers that they are serious about desiring the market introduction of HEVs and that they are prepared to use pricing instruments to stimulate their market uptake. The timing of the various measures could be a matter of discussion with the industry and STSc could help to facilitate those discussions.

Road pricing and high parking rates are used in both scenarios but they play a different role. In the first scenario, they lead to various high-tech solutions, a segregation of types of vehicles and a modest modal shift. This is a risky path since the scenario illustrates that problems tend to come back in aggravated forms and lead to a situation that is even more difficult to change then before (lock-in). In the second scenario, there is more initial openness to experiment and learn on a variety of options in niches and only use the pressure of these economic instruments when certain new options have proven their value. Thus they can contribute to more drastic reform that can eventually lead to a transition. Let us therefore look more specifically at the niches and options to induce such changes.

7.2 Explore the promise of various niches

The argument in the previous section already implies a plea to experiment and learn widely on the potential of various alternatives. Especially the second scenario has examples of new combinations of options (hybridisations) and forms of changing user behaviour that eventually led to a transition of the regime. The typical pattern is that new forms of user behaviour initially appear in niches, stimulated or induced by new technical options. Subsequently, a change of the selection environment via economic instruments or regulation stimulates those new user segments to grow.

Which of the new behavioural patterns will in practice be crucial is impossible to predict (another STSc, for instance, may reveal other possibilities) but it is clear that stimulating a variety of niches enhances the chances that such new links will emerge. The limited scope of this paper leads us to be careful in making strong claims on which niches to stimulate but the analysis does support the conclusion that several options, that get limited attention in current policies or are even looked at sceptically, could play a crucial role to move toward a sustainable mobility regime. Especially when looking at the second scenario, the following current niches play a crucial role:

- hybrid electric vehicles;
- fuel cell electric vehicles;
- city electric vehicles (CEVs);
- biofuels;
- multimodal transfer points;
- car-sharing.

In the second scenario, automatic vehicle guidance plays a prominent role.

The scenarios show that these technologies do not follow independent paths, each securing their own niche market, but that they get linked up in various ways. Furthermore, the transition in the second scenario, that does not develop in the first, stems from initially small groups of ‘first users’ in niches changing their behaviour and subsequent developments (stimulated by regime pressurising policies) in which these groups grow. This implies that policies seeking to exploit these possibilities should not just look at individual niches but be especially be alert on linkage possibilities as well as on new user patterns in these niches.

Below, for reasons of clarity of argument, we will discuss the various currently existing niches in order, also as a way to directly address the people working in those niches and the policy-makers concerned with them. Within these descriptions, however, we will emphasise the need to be aware of linkage possibilities with other niches as that offers most promise of inducing a transition.

7.2.1 City Electric Vehicles

At present, there is much debate on the potential of electric vehicles in general. Most attention goes to a wide variety of projects with converted internal combustion engine vehicles, i.e. heavy vehicles with a large battery pack that only give a driving range of 100 km or less. Small, lightweight electric vehicles have been demonstrated and are actually on the market (e.g. the Ford Th!nk, the Toyota E-com and the Nissan Hypermini) but these get hardly any attention.

The reason for this lack of attention is that transport planners are too much judging CEVs from the perspective of the current regime, seeing it as no alternative to conventional vehicles and fearing it could only become an additional vehicle in the household. The STSc exploration, however, shows that this may be the case initially but that in subsequent developments a CEV can play much more interesting roles, partly even inducing change processes towards a new mobility regime. Some of the following features stand out in the scenarios:

- CEVs may start as an additional car in a household but under specific circumstances it may subsequently become the first vehicle and eventually the only vehicle;
- starting as an individually owned vehicle, CEV could become part of a car-sharing system enabling the supply of a wider and more attractive range of mobility services;
- Initially, CEVs may be costly and attractive only for the wealthy. But with increasing production volumes the price could drop considerably to give it a wide applicability;
- The availability of CEVs could encourage city authorities to make or extend limited access zones which in its turn could prelude developments towards ‘sustainable cities’.

The challenge then becomes to explore under which conditions these features might be exploited. This necessitates carrying out various experiments with such vehicles under appropriate conditions, also trying to evaluate experiences across various locations. The vehicles presently available on the market could be a starting point for such experiments.

7.2.2 FCEV

Most transport planners see fuel cell vehicles as the ultimate clean technology for transportation. But they also think that large-scale application is probably still several decades away. All large automakers have programs on FCEVs, some even announced prototypes in a few years. Apart from the developers directly involved, most other relevant actors have a wait-and-see attitude.

FCEV technology indeed has a considerable promise but is also surrounded with a lot of uncertainty. The main promise is that emissions can indeed be extremely low, provided the primary fuel is sustainably produced. Uncertainty relates to cost, downsizing of the technology, primary fuel to use in connection with the need of on-board reformers.

[2] Check name !!

The technical and economic issues can only be left to the developers. The main issue for policy is to guard that the way FCEVs are experimented with and introduced optimally exploits its potential in sustainability terms. Concerning fuel cell buses this can for instance be done by an experimental set-up in which hydrogen is sustainably produced. This can help to create enthusiasm amongst various stakeholders (including riders) that ‘clean driving’ is possible which may also stimulate interest for this notion in the wider sense. Also, experiments would be preferred in which a Fuel Cell bus not only replaces a conventional bus but is part of a wider set-up tinkering with or moving towards chain mobility. Some more specific ideas on how this might be done can be inferred from the second scenario above in which fuel cell buses become an important element to help launch and enable the CiTrans concept.

Concerning fuel cell cars a warning is in place. Many, especially the automakers put forward that we should not move towards HEVs since FCEVs have much more potential as the ultimate clean vehicle. In the U.S. this has even been embedded in a new national research program called “The Freedom Car”. The result would be that conventional vehicles continue to dominate for another decade or two which implies that CO_2 emissions from transport will not be brought back for the same period. The scenarios illustrate that HEVs have the potential to reap the benefits much sooner and, moreover, it is contestable whether FCEVs should be cleaner than HEVs. With HEVs a drastic reduction of fuel consumption is possible, making biofuels and a closed CO_2 loop a much more viable option. Especially if HEVs would become the prime car-type in a mobility system based on a CiTrans-like concept the number of passenger-kilometres travelled by car could go down substantially. In such a situation, the contours of which might become visible in a decade or two, the issue of the necessity or advantage of an FCEV is much better to assess. Therefore, it is recommended to stimulate the market introduction of HEVs now and not wait for the fuel cell car.

7.2.3 Fuels

The European Commission is considering to set a target that by 2010 the share of biofuels should be at least 6%. This should be achieved via various taxation measures making biofuels substantially cheaper than conventional fuels.[3] Such a measure should indeed be recommended and supported by various national programmes. It is especially useful to seek ways to combine the use of biofuels with efforts to stimulate the further development and market introduction of much cleaner vehicles, notably HEVs and fuel cell buses. These vehicles are also much more fuel efficient which makes it also easier to achieve longer ranges with gaseous fuels which have the advantage that they usually burn cleaner than liquid fuels.

7.2.4 (Multimodal) transfer points

Train and bus stations are existing examples of transfer points. In the past decades there have been many attempts to stimulate various forms of chain mobility by new transfer point concepts like P+R and ‘transferiums’. At present, transport planners are rather sceptical about the potential of stimulating chain mobility and the issue has dropped on the political agenda.

Especially the second scenario, however, illustrates that the potential can be enormous. Characteristic of past attempts to realise and stimulate use of transfer points is that these were rather isolated elements trying to link an existing car and an existing public transport system. In the scenario, such attempts are part of much more encompassing strategy to boost city liveability. They link the growing interest in limited access zones, car-sharing concepts, upcoming CEVs, policy to prioritise public transport, high parking rates, etc. Once the

[3] White paper European transport policy for 2010: Time to decide (Sept. 2001).

functionality and use of such combinations passes a certain threshold the process can become self-reinforcing since it becomes ever less attractive to use the private car. The main issue then is that an encompassing and consistent long-breath policy strategy is needed to realise this. This requires a lot of experimentation with various elements of it in different locations and also to try and learn across these projects, in the Netherlands as well as abroad.

7.2.5 Car-sharing

Car-sharing has been and is stimulated by the Dutch ministry of traffic and transport but it is seen as something interesting only for limited market niche. In the current situation, this may be true but the second scenario shows that car-sharing can also partly stimulate and become part of a system of chain-mobility. The limit to further growth of the concept at present is that it is too much seen as an isolated concept. There are various ways to see car-sharing as part of a more encompassing mobility system, attempting to satisfy a variety of mobility needs, e.g.

- Seeing car-sharing as part of a mobility chain, implying that car-share organisations start to think from the perspective of offering a mobility service rather than a vehicle service;
- Shared car depots at train stations and other transfer points create the possibility for people to pick up a car at the destination part of their trip, thus providing an additional link in a mobility chain. Attempts to explore this further could build further upon recent experiences with such schemes in France (Praxitèle) and Switzerland (CityCar in Martigny).
- Create sensativity that people may have needs for a different type of vehicle under different circumstances and offer a range of vehicle types. Especially innovative types of vehicles could well be experimented with in such a setting. If the experiences are positive, car-sharers can be a good starting point to ‘spread the word’ among the wider public.

Seeing car-sharing thus as an element in a transforming transport regime rather than in a existing one opens up a variety of new concepts and ideas that could be further explored in various experiments.

7.2.6 Automatic Vehicle Guidance

A considerable amount of research is done on the technical side AVG. Transport planners think that AVG eventually has a large potential to tackle highway congestion but that the problems to realise it in practice will be large. It will probably require a major political effort with enormous infrastructure investments to realise it in practice, as was the way it was introduced in the first scenario. Given typical political dynamics such decisions is likely to be taken only when problems have got a lot worse than at present. ‘Betting’ on AVG to tackle highway congestion is than also betting on a risky path with high societal cost for a considerable period.

The second scenario also has the outcome that highway congestion is a lot less than at present but it realises this not by a high-tech approach but via a conceptual transformation approach. Transport planners may consider this wishful thinking but the scenario shows that by using plausible patterns of socio-technical dynamics this could well be achieved. On the basis of this we were able to give specific recommendations for the various niches on what seems to be a good strategy for the near term. Such a strategy looks far less risky than betting on AVG. Of course, research on AVG could be continued since it may well render various technologies that might eventually also be useful in a different type of mobility system.

8 Discussion

We started by sketching the problems of the traffic and transport system and the problems policy-makers encounter in tackling these problems. In our assessment, these policies have several shortcomings which are partly related to problems in assessing what the potential of various alternatives are. Scenario analysis could help them explore this but existing scenario-methods lack the attention for socio-technical change that is crucial in transitions.

We presented the STSc method as an alternative that does allow exploration of the socio-technical dynamic and illustrated this in two scenarios. Although we had to be brief in this paper, the two examples are clear illustrations that the methodology can indeed lead to scenarios in which new concepts and combinations can emerge, not as a *deus ex machina* but as the result of plausible new linkages under specific conditions. They also illustrate that it is quite plausible that the behaviour of travellers can change when the conditions are right.

Finally, using the scenarios, we have been able to develop policy recommendations on how to stimulate, induce and encourage developments towards sustainable mobility. Not in the sense of giving clear guidance on how to realise a specific end situation but in the sense of enhancing the changes that various developments in niches can link up to create new elements of a transformed mobility regime.

Concerning the shortcomings of existing policies presented in the beginning of this paper notably (1) fragmentation of problem solving, (2) weak method to assess potential of alternatives and (3) weak method to choose and tune policy instruments, the STSc approach proposed here offered at least a partial remedy for each of those. Within the limitations of this paper we could not elaborate and evaluate the method in full but the least we can claim on the basis of the argument above is that it provides a promising contribution to tackle the problems described more adequately.

9 Literature

Amara, R., 1988, ‘What have we learned about forecasting and planning’, *Futures*, August 1988, pp. 385-401

Amara, R., 1989, ‘A note on what we have learned about the methods of futures planning’, *Technological Forecasting and Social Change*, Vol. 36, pp. 43-48

Ayres, R.U., 1989, ‘The future of technological forecasting’, *Technological Forecasting and Social Change*, Vol. 36, no-1-2, pp. 49-60

Coates, J.F., 1989, ‘Forecasting and planning today plus or minus twenty years’, *Technological Forecasting and Social Change*, Vol. 36, pp. 15-20

Coates, J.F., Mahaffie, J.B., and Hines, A., 1994, ‘Technological Forecasting 1970-1993’, *Technological Forecasting and social change*, Vol. 47, pp. 23-33

Deuten, J.J., A. Rip en W.A. Smit, 1998, *Nieuwe werelden… Met micro-optica: Scenario's en scripts, en wat deze impliceren voor micro-optica onderzoek aan de Universiteit Twente* (Enschede: Universiteit Twente)

Elzen, B., Geels, F.W., Hoogma, R., Schot, J.W. and Te Velde, R., 1998, *Strategieën voor innovatie: Experimenten met elektrische voertuigen als opstap naar marktontwikkeling,* Report for the Dutch Electricity Utilities (SEP), 208 pp.

Geels, F.W., 2002, ‘Towards sociotechnical scenarios and reflexive anticipation: Using patterns and regularities in technology dynamics’, Williams, R. and Sorensen, K ???., (editors), *Shaping Technology, Guiding Policy: Concepts, Spaces and Tools*, Edward Elgar, pp. 355-381 (forthcoming)

Huss, W.R., 1988, 'A move toward scenario analysis', *International Journal of Forecasting*, Vol. 4, pp. 377-388

Kemp, René, Arie Rip and Johan Schot, 2001, "Constructing Transition Paths through the Management of Niches", in Raghu Garud and Peter Karnøe (eds.), *Path Dependence and Creation*, London: Lawrence Erlbaum Associates, Publishers, pp.269-299.

Leonard-Barton, D. (1988): "Implementation as mutual adaptation of technology and organisation", *Research Policy*, Vol. 17, pp. 251-267.

Murdick, R.G. and Georgoff, D.M.,1993, 'Forecasting: A systems approach', *Technological Forecasting and Social Change*, Vol. 44, pp. 1-16

Nelson, R.R., 1994, 'The Co-evolution of Technology, Industrial Structure, and Supporting Institutions', *Industrial and Corporate Change*, Vol. 3, No. 1, pp. 47-63

Nelson, R.R., 1995, 'Recent Evolutionary Theorizing About Economic Change', *Journal of Economic Literature*, Vol. 33, pp. 48-90

Pistorius, C.W.I. and Utterback, J.M., 1997, 'Multi-mode interaction among technologies', *Research Policy*, Vol. 26, No. 1, pp. 67-84

Porter, Alan, L., A. Thomas Roper, Thomas W. Mason, Frederick A. Rossini, and Jerry Banks, 1991, *Forecasting and management of technology*, John Wiley & Sons, New York

Rosenkopf, L. and Tushman, M., 1994, 'The coevolution of technology and organization', in: Baum, J. and Singh, J. (eds.), *Evolutionary dynamics of organizations*, Oxford: Oxford University Press, pp. 403-424

Sapio, B., 1995, 'SEARCH (Scenario Evaluation and Analysis through Repeated Cross impact Handling): A new method for scenario analysis with an application to the Videotel service in Italy', *International Journal of Forecasting*, Vol. 11, pp. 113-131

Schoonenboom, I.J. and Van Latensteijn, H.C., (1997), 'Toekomstonderzoek en beleid: Goede intenties en kwade kansen', in: *Toekomstonderzoek en strategische beleidsvorming: Probleemverkenningen en praktijktoepassingen*, Report from NRLO, no. 3, Nationale Raad voor Landbouwkundig Onderzoek, The Hague, pp. 9-24.

Simmonds, W.H.C., 1989, 'Gaining a sense of direction in futures work', *Technological Forecasting and Social Change*, Vol. 36, pp. 61-67

Weterings, R., Kuijper, J., Smeets, E., Annokkée, G.J., and Minne, B., (1997), *81 mogelijkheden voor duurzame ontwikkeling*, Eindrapport van de milieugerichte technologieverkenning, in opdracht van Ministerie van Volkshuisvesting, Ruimtelijke Ordening and Milieubeheer.