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Coping with Uncertainty

An Expedition in the Field of New Transport Technology

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COPING WITH UNCERTAINTY

An Expedition in the Field of New Transport Technology

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Abstract

Many decisions of mankind are rational only to a limited extent. This holds for individual travel behaviour, but also for long-range strategic decisions on transport systems or transport technology. In any decision problem coping with uncertainty is the most critical element.
The introduction of new transport technology is surrounded by many types of uncertainty. For example, there is uncertainty about the pace and extent of adoption of new technology and there is uncertainty about the impact of new technology in terms of an increased sustainability or increased efficiency. This article attempts to map uncertainty surrounding new transport technology and to identify ways to deal with uncertainty in policy making. The findings will be illustrated with electric vehicles, particularly with two specific strategies to deal with uncertainty, i.e. interactive technology watching and experimentation in a market niche. The article concludes with a discussion of success factors that influence the outcomes of such strategies.

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1. Homo Mobilis and Homo Economicus

Conventional wisdom in transport science suggests that transport movements serve to overcome physical distance barriers. Such movements are – apart from a few rare cases like leisure trips without a destination – necessary because of the geographical separation of various activities (residential, employment, social etc.). Since transport is regarded as a burden, the rational decision-making paradigm then suggests that it is wise to minimise the transport effort. In particular, welfare theory – one of the comer stones of transport economics – argues that it is in the interest of the 'homo economicus' to minimise travel costs (pecuniary, time-wise or psychological).

This assumption lies at the basis of many utility-based demand studies (e.g., discrete choice models) but has also created the foundation of many aggregate transport studies (such as quadratic assignment models, linear programming models for modal split or route choice and the like). In fact, the overwhelming majority of transport studies looks into physical movement as a sacrifice. If this basic assumption were valid, then a series of intricate and intriguing questions emerges. How come that the action radius of modem men tends to increase structurally (see, e.g., van Doren, 1991)? How is it possible that the 'law of conservation of travel time' is rather robust (at least in metropolitan areas), but shows an increasing trend for longer trips? Is the modem 'homo mobilis' essentially a 'homo economicus' or is he driven by other – also rational – instincts?

In a recent study on 'slow motion' (see Nijkamp and Baaijens, 1999) a review of motives in favour of other – less fast and (perhaps) more environmentally benign – modes of transport was given, based on the recently developed concept of a 'time pioneer'. The argument is that it may – from both an individual and a collective welfare perspective – be rational to reduce travel speed. Empirical research however, demonstrated that the willingness among travellers to choose 'slow motion' options is disappointingly low. On the contrary, the trend is towards more speed and a larger action radius. Does this mean that the 'homo mobilis' is not a rational decision-maker? It should be noted that the basic hypothesis in welfare theory is that the individual seeks to maximise his (her) own welfare, based on the assumption of perfect information and on the absence of externalities, bandwagon and image effects, and the like. There is quite some literature, in particular in the 1960s geography, which convincingly demonstrates – both conceptually and empirically – that the choice of the actual location of firms can differ significantly from the theoretical optimal location (see e.g., Wolpert, 1964). This is then explained by the prohibitive role of high search costs to find the optimum optimorum. Choice makers tend to be often satisfied with a second-best – or even third-best – location, as they are not driven by the exclusive goals of profit seeking behaviour. The theoretical basis of this ‘satisficing’ behaviour has been given by Herbert Simon in this theory on ‘bounded rationality’ (see Simon 1952).

Apart from the costs involved in gathering perfect information, there is also a social driving force. Location and travel decisions are not taken in a Robinson Crusoe economy on an isolated island, but in social interaction with others (the notion of the ‘homo socialis’). For example, the need to live near one’s relatives may lead to a residential location decision that is not optimal from a cost-minimising viewpoint. Consequently, there is quite some evidence that travel decisions are not exclusively governed by rational – cost-minimising, utility-maximising or profit-maximising – behaviour. Theoretically speaking, this would imply a specification bias in many of our behaviour transport models. In any case, the ‘homo mobilis’ is faced with many uncertainties in his (her) travel choice; perfect information is an illusion. This recognition may have serious implications for the precise value of transport models and limits seriously the scope of cybernetics oriented engineering approaches in transport science.

There is still another issue. To assemble proper information may be too costly, but the human ability to digest all relevant information is also limited. Consequently, the available or existing information may also be selective and has to be interpreted from the subjective perspective of the user or decision-maker. Furthermore, if travel information has to be transmitted to road users, the question is whether a particular road user needs exactly the given information. In many cases, he may be willing to receive additional or other information. This is clearly reflected in an early statement of March and Simon: “*...the vast bulk of our knowledge of fact is not gained through direct perception but through the second-hand, third-hand, and nth-hand reports of the perceptions of others, transmitted through the channels of social communication. Since these perceptions have already been filtered by one or more communicators, most of whom have frames of reference similar to our own, the reports are generally consonant without the filtered reports of our own perceptions, and serve to reinforce the latter*” (March and Simon, 1958, pp. 153).

The previous remarks do not only apply to daily or routine decisions. They are equally relevant for strategic decisions of a long-range nature on transport systems or transport technology. Coping with uncertainty is essentially the most critical element in any decision problem. This question extends far beyond stochastic or probabilistic approaches to uncertainty management. In the sequel of this article we will address in particular uncertainty issues in the field of transport systems technology, but most remarks apply also to uncertainty problems in the broader area of transport management and policy.

2. Exploring the Future

In the past decades we have observed a great variety of attempts to come to grips with an uncertain future. This is clearly exemplified by the path breaking work of Kahn and Wiener on "The Year 2000", published in 1967. The question is whether much progress has been made in the past decades. This provokes in particular a complicated methodological issue, as it asks whether better understanding does also lead to better forecasting. Some remarks on this issue are in order now. Explanation is a process of logical deduction and empirical validation, in particular in the context of repetitive events. In a strict sense it would be impossible to subject "unique" events to a scientific explanation. In any case, an explanation in a probabilistic statement of an "if-then" nature, which – given a predetermined domain - is able to make a scientifically founded statement on the possible or probabilistic occurrence of events as part or as a result of events which fall outside the a prior, defined domain. Thus, an explanation has quite some restrictions. Its validity is limited by prior hypotheses and by methodological constraints.

From a methodological perspective there is not so much distinction between explanation and forecasting, apart from an obvious difference between prospective and retrospective thinking. But also forecasting is a process of logical analysis on the basis of empirically verifiable relationships, with the only exception that exogenous variables - falling outside of the forecasting domain - cannot be empirically observed, but can at least be hypothesised (e.g. on the basis of plausible reasoning). But in principle one might argue that forecasting = explanation.

In the history of future studies we may distinguish various approaches which aim to offer a scientific underpinning for statements on future events. Examples are the following:

- *Blueprint thinking.* In this mode of thinking the basic assumption is that it is possible to define a feasible amount of targets in the future, which can be realised through the right use of instruments. The idea of a "makeable" society – very popular in the seventies and eighties- is illustrative for this approach.
- *Normative thinking.* Here the idea is that a society may evolve according to a priori fixed, normative -sometimes ethical- criteria.
- *Nested thinking.* This is based on the conviction that the future as a whole is difficult to forecast, but that certain parts or aspects (e.g., demography, technology) may be mapped out with a sufficient accuracy.
- *Fiction thinking.* This type of future thinking is based on a non-historical approach and questions the limits posed by past constraints.
- *Scenario thinking.* This has become a popular way of analysing the future. It presupposes the design or existence of meaningful – not necessarily realistic - future images, but it demands that such images meet strict methodological requirements such as internal consistency and a bridging between the present and the future. Such scenarios are politically not committing, but offer a spectrum of future developments (e.g. Nijkamp and van Geenhuizen, 1997; Nijkamp et al., 1998).
- *Evolutionary thinking.* This approach is not based on normative or policy views, but assumes some sort of adjustment mechanism in human behaviour (e.g., resilience), which drives living organisms or systems towards "continuity in change". It also draws attention to a phenomenon named path dependency, meaning that future moves in policy making are constrained by decisions made in the past.
- *Learning* thinking. This mode of thinking has already a long history (see, e.g. Harvey, 1967) but has recently become fashionable in connection with evolutionary thinking. Popular concepts in this framework are the learning decision-maker, the learning organisation, the learning city, etc. This principle forms a contrast with blueprint and normative thinking and avoids "linear" thinking. It is based on a blend of positive and negative feedback responses in a dynamic choice environment (e.g. Stacey, 1992).

The previous observations hold also for transport technology. The high risks of new technologies may hamper a rapid introduction. But also the acceptance attitude of the user may cause a stumbling block. These issues will be further discussed in the next sections.

3. The Uncertain Roads of Transport Systems

Transport is the spatial projection of societal dynamics. The 21st century will see a variety of new social and technological trends which will influence the way in which transport is supplied and utilised (cf. Becker, 1997). At present a wide range of social phenomena, including rising incomes, increased leisure time, new communication technologies, an ageing population and a declining role for the traditional family, are changing the nature of the demands we place on transport. In response to new techniques of production, shipping and the growth of markets, economic activities are also changing. Institutional reforms such as privatisation and deregulation have changed transport in ways that are not yet well understood. At the same time increasing use of petroleum resources for travel and transport has raised concerns about the eventual depletion of fossil fuels as well as its contribution to global warming and decreases in urban air quality. But from a methodological perspective we have to ask ourselves: do we have the scientific apparatus to forecast uncertain future developments, trends or events, particularly those that are crucial in the adoption of new transport technology?

New technology may affect the transport system in two different ways. First, there is *optimisation* of the current transport system by using existing potentials, and secondly, there is the much more comprehensive *structural change* of the transport system. A good example of the first is the electric vehicle because the concept of individual cars remains unaffected in merely challenging the type of traction system. However, if electric vehicles are used in new concepts of carpooling and mixed forms of private and public transport (using busses) attention moves to structural changes in the transport system (Rutten et al., 1998). Accordingly, the latter case involves much more uncertainty.

Uncertainty can be tackled from various angles. For example, Rowe (1994) in elaborating uncertainty as the “absence of information”, makes a division into various dimensions (van Geenhuizen et al., 1998):

- *Temporal* uncertainty. This refers to the future state of the transport system (prediction uncertainty) and related systems, but also to the past states of these systems.
- *Structural* uncertainty. This refers to the complexity of the transport system in modelling. Structural uncertainty depends on the number of parameters and interaction used in models to describe a situation or development. The key question is how well the models represent reality.
- *Metrical* uncertainty. This is concerned with difficulties in measurement of the system. Central issues here are precision and accuracy (validity). Such uncertainty plays a role for example, in measuring preferences of travellers in public transport.
- *Translational* uncertainty. This refers to the communication of the results of analysis and modelling in a policy context. Goals and values of the stakeholders are the main issue because these affect the interpretation of the results and the related effort in consensus building.

All four dimensions of uncertainty occur in any situation and reinforce each other. The last dimension – translational uncertainty - indicates the importance of stakeholders in policy making. Their interests may be different, dependent upon their goals and means, problem perception and interpretations. An interesting example in this framework is the estimation of future traffic flow and the estimation of costs of large transport projects (Skamris and Flyvbjerg, 1997). A compilation of before-and-after-studies of various large projects shows considerable cost overruns (of 50-100%) and traffic forecasts that are remarkably optimistic (by 20 to 60%). The differences between forecast and actual costs and traffic cannot be explained primarily by structural uncertainty. By being strongly consistent and one-sided the uncertainty that has entered is much more of the translational type and needs to be seen - as Wynne (1992) puts it - as a "social construct".

By adopting the perspective of policy making and by conceptualising the relevant part of reality as a system, four classes of uncertainty can be distinguished (see the introduction of this special issue):

- Uncertainty about the future *outcomes* of the system
- Uncertainty about the future behaviour of *external influences*

- Uncertainty about *system behaviour,* connected with the above mentioned structural and metrical uncertainty
- Uncertainty in the *selection of policy measures,* including *guiding values.*

This classification serves as a framework in our identification of uncertainty in policy making on the adoption of electric vehicles in the next section.

4. Policy Making concerning Electric Vehicles

The development of electric vehicle technology during the end of the 19th and beginning of the 20" century exemplifies highly dynamic processes with unexpected outcomes (Isoard, 1996; Cowan and Hulten, 1996). At the start of the market introduction at that time electric cars were far ahead compared with gasoline cars. The gasoline engine was considered to be inferior because of the noise it produced, and its unsafe and dirty character. There was also a need for some additional but complicated technical innovations. However, the strategic behaviour of a few gasoline car producers - especially their move to a mass market and use of specific marketing tools - has given the gasoline car a position ahead. Due to subsequent advantages from increasing returns to scale (and lock-in), the gasoline engine could maintain this position whereas competing technologies faced progressively greater difficulty in entering or surviving in the market. This example shows the ill-predictability of the winning technology - connected with various small events (or actions) - and the non-superiority of the selected path.

A detailed analysis of the adoption of electric vehicles as it is to-day and of concomitant policy making brings a differentiated “landscape of uncertainty” to light (van Geenhuizen and Schoonman, 1999; Mulder et al. 1996; Rutten et al., 1998). The key uncertainty belongs to the behaviour of the system, i.e. user acceptance, and to the future outcomes of the system (Table 1). Accordingly, it is difficult to select the appropriate policy measures. In fact, we are not able-to model user acceptance behaviour and policy impacts in such a way that it helps to predict the adoption of electric vehicles and to get insight into underlying factors. Metrical uncertainty, of course, contributes to the lack of adequate prediction results. For example, despite progress there are still measurement problems to solve in studies focusing on stated preference (of users) (e.g. Golob et al., 1996) and on opinions (of experts) (e.g. Mulder et al., 1996). The uncertainty that stems from the *critical* user acceptance seems connected with performance and price aspects of electric vehicles, i.e. a relatively small range, danger of dead battery and relatively expensive to buy, but there is more. Over the past decades cars have increased freedom, mobility, prestige, and a whole lot more in the life of individuals (e.g., Marsh and Collet, 1986). It may take therefore, a number of years to add the totally different attribute of environmental ideals to this range. Moreover, electric cars may never attract drivers that are moved by car appeal going far beyond merely functional transport. Knowledge of such appeals and their influence is too small to date in order to contribute to sound predictions. The same holds for uncertainty in the case of mixed private-public transport using electric busses. Here, we may expect user resistance based on a general aversion against all modes that are different from the individually used car. On the other hand, environmental motives may become strong in the segment of second cars in households and in the segment of business cars. Both are growth markets, and we may be able to predict how fast these segments will grow in the next coming years.

Table 1 Uncertainty in policy making for electric vehicles

Element	**Details**	**Strength of uncertainty**
Future outcomes	- Achieving aimed results - Causing negative side-effects	Strong Strong
External influences	- Behaviour of actors in dominant technologies (resistance from lock-in), such as conventional car manufacturers and fuelling industries - Growth of customer segments with large opportunities (second cars, business cars)	Weak Weak
System behaviour	- The time that high performance batteries and fuel cells are available at a competitive price - Divides within the technology, such as low and high temperature battery systems, leading to potential incompatibilities - Critical user acceptance: Willingness to pay extra and bear inconvenience for environmental gains; willingness to "lose freedom or independence" in a shift to non-private transport	Weak Weak Strong
Selection of policy measures	- Effectiveness of measures, e.g. of incentives, subsidies - Missing guiding values	Strong Weak/strong

The uncertainty in future outcomes of the system can be summarised as follows. Due to uncertain system behaviour and uncertain inputs, the latter mainly from external factors, we are not able to predict the outcomes of the system in terms of a move towards reaching policy aims, such as sustainable energy aims and prevention of externalities (noise, emission). The same holds for adverse effect, like an increase in overall car mobility, due to the use of electric cars as second (third) cars in households. Buying electric cars may serve as a kind of justification, whereas without a pushing policy of electric cars no second or third cars would have been bought.

As far as technology is concerned, uncertainty seems far less strong. Battery and fuel cell technology will need some more 5 years before these can be used in high performance and cost competitive electric vehicles. Research on improved performance and reduction of production costs of light weight rechargeable solid-state lithium-ion batteries is of particular interest. Research focuses on the stability, compatibility, and electrical properties of the battery components. World-wide research also focuses on cost reduction of polymer fuel cells, among others by reducing the amount of platinum catalyst. The uncertainty that is involved seems to be “manageable” in that it can be reduced by increased research and development efforts (van Geenhuizen and Schoonman, 1999).

In terms of *guiding* values, an important missing link in policy making to date is a clear vision on the functions of transport, other than the straightforward bridging of distance. These other functions may be strongly (social) psychological, like a gain of individual freedom, increase of power, and gain of identity. In a situation in which it is generally accepted that car driving only serves the functional bridging of distance, designing a policy to enhance the adoption of electric vehicles is less difficult compared with a situation without such a guiding value.

The above circumstances indicate a large uncertainty in the selection of policy measures to enhance the adoption of electric vehicles. The way how policy makers may deal with uncertainty will be discussed in the next section.

5. Strategies to Cope with Uncertainty

There are many strategies for coping with uncertainties, each using different methods. The following strategies can be distinguished (e.g., Friend and Hickling, 1997; van Geenhuizen et al., 1998; van Geenhuizen and Thissen, 2001):

- To *ignore* uncertainty, take policy measures, and see what will happen; while this may be the easiest option for the short term, it means in fact accepting large uncertainty with respect to the policy outcomes.
- To *identify* and, if possible, *specify* uncertainty. This enables the policy maker to act consciously in the presence of uncertainty. The classifications above may be helpful in this respect. Methods to identify and specify uncertainties include scenario analysis (e.g. for uncertainty in the system's surroundings) (Nijkamp et al., 1998; von Reibnitz, 1998; Schwartz, 1991), development of alternative system models to account for alternative structures, and determination of confidence bounds for data and model parameters.
- To *do nothing* and let uncertainty be reduced by time; this approach means delay, and involves a good chance that, while some uncertainties will disappear, new ones will emerge. Doing nothing may be a positive choice, based on a vision in which the self-organising capacity of society and particular interest groups is given priority and is trusted to achieve satisfactory outcomes.
- To *reduce* uncertainty. This can be done in different ways. First, by additional research or better integration of existing knowledge; this might cover the range from the collection of new data to the application of advanced methods of integrated modelling and explorative modelling to more clearly distinguish between possible and impossible developments, and to identify critical events and bottlenecks. Second, by pushing the uncertainty onto someone else, which generally will involve costs (e.g., insurance premiums, compensation). Third, by negotiating with others whose behaviour is uncertain but has a significant impact on the desired policy outcomes. This may involve processes of participatory policy development, and/or agreements with policy makers in adjacent fields.
- To *accept* uncertainty, and *act consciously* in its presence. Here, too, different strategies are possible. A robust policy may be selected, i.e., a policy that will do well in most possible future circumstances. Or a flexible policy is designed, i.e., a policy that is adaptable to the future course of events (e.g. Walker et al., 2001).
- To see uncertainty not as a threat, but rather as an *opportunity* to creatively shape the future. Rather than emphasising a choice for a presently available policy option, this approach calls for development of a vision that provides the guiding principles for present and future action, such as experiments and other learning exercises that may underpin policy measures (Stacey, 1992).

It seems self-understanding that the above strategies do not exclude each other but often complement each other. We now turn to two complementary roles adopted by the Dutch government in an attempt to identify and specify uncertainty, and learn about the future by experimentation, i.e. the role of technology watcher and the role of innovation agent (Grin et al., 1997; Rutten et al., 1998).

The role of *technology watcher* includes a systematic monitoring of technological developments and understanding of these developments in terms of repercussions for policy. The developments are positioned in a frame of five layers which provides the appropriate background to assess the relevance of the new technology in transport. These layers include the one of components (such as batteries and fuel cells in the case of electric vehicles), the application (e.g. concepts of propulsion), the type of vehicle (cars, busses), the transport concept (short or long distance transport), and the transport system (such as multi-modal commuter transport systems). The main activities of technology watching are:

(1) to collect useful information on a particular technology and its potential markets
(2) to arrive at a broad interpretation of this information leading to score matrices for the technology on specific criteria
(3) to establish various rounds of interaction with policy makers, policy analysts and researchers in order to focus on policy relevance
(4) to establish a synthesis and preliminary conclusions
(5) to distribute the results to policy makers and other stakeholders.

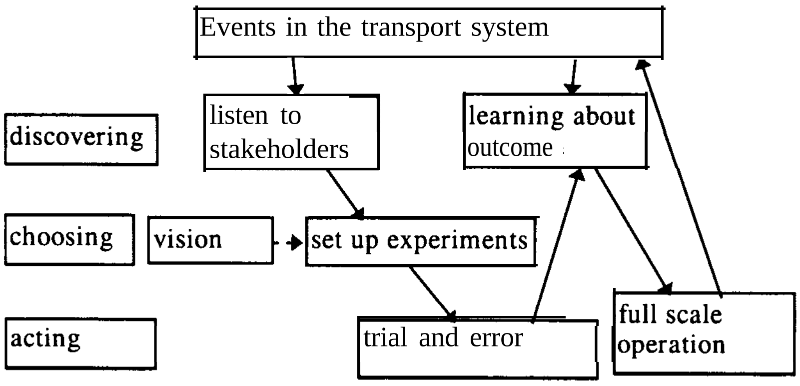
What is new in this approach is the acknowledgement of the fact that each of the above activities includes a number of *choices*, for which a solid and transparent argumentation needs to be provided preferably in interaction with important stakeholders. Apart from the selection of the technology itself, there is for example the selection of the type of information to be collected (activity 1) and the criteria to be used in a first interpretation (activity 2). The key activity of course, is to scan the technology for *policy relevance* (activity 3). This includes both-an assessment of direct impacts and an exploration of (potential) use of the technology according to various criteria. The latter activities may include various rounds of scenario analysis in order to learn about the technology. In terms of results, the methodology may not only clarify the potential role of the technology but also the role of factors that advance or prohibit this role.

It is increasingly acknowledged that a participatory (or *interactive)* structure is a key prerequisite for success of the methodology. This means a continuous input from the side of independent experts and users of the technology at hand. There is a trend to consider a *broad* group of stakeholders as relevant, i.e. also including actors on the supply side of the new technology, like manufacturers and sponsors, and organisations that contribute to the embedding of the technology (Grin et al., 1997). This broad input serves to cover the perspectives of all influential players at hand and, accordingly, to increase support of them. But there is also a danger here. It may happen that results are achieved without sufficient reflection of real-life power structures, thus being unrealistic in a sense. This calls for a delicate design of participation to arrive at strong outcomes that have sufficient *"authority"*.

As previously indicated, in its role of *innovation agent* the government is actively involved in a successful implementation of the new technology. One way of doing this is to experiment with a new technology in a relatively small and protected niche of the market, and this is exactly the policy for electric vehicles in the Netherlands. The major experiment deals with daily commuting between the cities of Rotterdam and Zoetermeer, in which electric busses are used to bring commuters to their work at the location of the Ministry of Transport and Waterworks in Rotterdam. Such an experiment serves various important goals, like to demonstrate the use of the technology and to test the technology on user value and acceptance. Technology experiments in niches like this one, require the identification of the right market niche, a smart combination of resources and the involvement and interaction of the right stakeholders. More importantly, network management is involved in terms of shaping and reshaping the relationships between stakeholders (de Bruijn and ten Heuvelhof, 2000). The ultimate goal of such experimental small scale implementation is to proceed in the adoption itself, while learning about advancing and hampering factors. The outcomes then serve as input for a further development and testing. Learning experiments like these match with a planning culture that is relatively new, i.e. vision-based planning (Figure 1).

An essential difference with conventional planning approaches is that there are no predetermined goals to be achieved by using new technology and no predetermined policy measures that serve the realisation of these goals. Rather, there is a broad vision on new technology and transport, and there is a continuous interaction (communication) with stakeholders. Information from these two sources provides the basis for conducting various experiments. Further, the learning derived from a series of experiments (trial and error) may arrive at a stage in which it enables to underpin decision making.

Figure 1 Vision-based Planning



Source: van Zuylen, in van Geenhuizen et al. 1998.

Similar to the previous discussed role of technology watching, the experiments need to be selected, designed and carried out in such a way that there is a broad coverage of causal factors as well as a broad support from stakeholders for the results, without losing sense for real-life power relations. Note that vision-based planning is an interesting alternative to conventional practices only in specific cases. It is not regarded here as a general solution to problems of uncertainty in transport policy making, for the simple reason that particular policy questions are concerned with large scale infrastructure projects like high-speed rail connections and Maglev systems. In these cases, experimentation in a niche and learning based on trial and error are not useful.

6. Variation in Europe

There are different national planning methodologies in Europe. For example, in some countries there is an emphasis on the input of users in technology assessment, whereas in other countries experts have a prominent role. The importance attached to reduction of uncertainty in policy making also varies from country to country, based on differences between national cultures (de Jong, 1998; Stough and Rietveld, 1997; van Zuylen et al., 1998b).

What roles governments actually play with regard to promising transport technology is very much dependent upon a blend of factors. In policies for introduction of electric vehicles in various European countries in the mid 1990s, we observe large differences that can hardly be ascribed to differences in planning culture only (IAEA, 1995; Weber and Hoogma, 1998) (Table 2). Rather, various meso- and macro economic factors seem to count. For example, the Netherlands compares with Germany in the dominant type of electricity production. In both countries, electric vehicles using batteries would be powered with electricity from non-sustainable sources (coal and gas), a situation in which the environmental gains of the technology can be questioned and the public image of electric vehicles seems relatively weak. Note that this might change if hydrogen powered fuel cells are used.

Other important factors that differentiate between countries include price and availability of electricity, and the match of electric vehicles with accepted problem situations such as the recognition of air pollution in cities as a severe problem and general environmental problems. Furthermore, the industry structure seems important with monopoly and oligopoly enabling a smooth involvement of national governments. There is one factor of which the influence is not quite clear, namely the structure of the government system. In Germany, a decentralised system would hamper consensus building on the need for adoption of the new technology, due to the involvement of different governments on a lower level. However, in the case of Switzerland a similar government structure would not have a hampering influence, most probably because the new technology is not questioned due to its zero emission character. The Swiss government also acts as a conditioning agent in the establishment of a kind of “clean air act”. According to this policy, a total of 200,000 electric vehicles are planned on the road in 2010, corresponding to about 8% of the number of cars in the country today (AssoVEL, 1998).

Table 2 **Factors in macro (meso) systems and government roles in EV adoption**

Country	**Factors**	**Role of Government**
France	*Advancing factors* Need for outlet for nuclear power Recognition of air pollution in cities as a severe problem Centralised government Industry monopoly and oligopoly	Subsidy for EV purchase Co-ordination of initiatives Funding of R&D
Sweden	*Advancing Factors* EV matches environmental policy EV is nearly zero emission Low price of electricity	Support of R&D Support of demonstration and procurement programs
Germany	*Prohibiting Factors* Non-renewable energy as basis and full emission (coal firing) Decentralised government Fragmented electricity industry	Modest role (recently increasing)
The Netherlands	*Prohibiting Factors* Non-renewable energy as basis and full emission (gas firing) Fragmented electricity industry but high co-operation	Modest role: Support of R&D Support of experiments in niche (collective transport)
Switzerland	*Advancing* EV matches environmental policy EV is zero emission	Clean Air Act Co-ordination and subsidisation of pilot programs Subsidy for EV purchase

7. Concluding Remarks

Transport is a complex activity that touches upon many different human activities. As a result, policy making is subject to uncertainty, a situation that calls for a strong awareness in the design of policy measures. This article has mapped out the landscape of uncertainty in the adoption of new technology in transport. In addition, it has considered various ways to deal with uncertainty, in particular two new roles of the government in the Netherlands, i.e. technology watching and experimentation in niche markets to advance adoption. What seems to be crucial for success of both strategies is the ability to create a sense of urgency among the relevant stakeholders in involving them in the interaction at hand. At the same time, the results need to mirror real-life power relationships between stakeholders. This serves not only a large coverage in terms of influences, but also a sufficient support for and "authority" assigned to the results. The latter is clearly necessary because the results of this type of new strategies are often under-used by decision makers.

Moreover, one needs to be aware of the potential dynamics in external factors, meaning shifts over time in stakeholders and upcoming new technologies. As we have seen in the early history of electric vehicles, small events may cause a leading position of inferior technology and a reinforcing of this position over time. The latter phenomenon would have two implications for technology watching, i.e. to cover a relatively broad spectrum of technologies and to identify the above indicated small but potentially very important events.

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