GENERATING A `WINDOW OF TECHNOLOGICAL OPPORTUNITY'; A NEW CHALLENGE FOR IMPLEMENTING SUSTAINABILITY ORIENTED TECHNOLOGIES IN TRANSPORT

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Abstract

This paper revolves around the issues of technological change and the urgent need from the perspective of the concept of sustainability, to reduce the impacts caused by transportation. Therefore attention is paid to the knowledge provided by technology dynamics on technology development, the network theory of public management on the role of the government (in cooperation with the private sector) in generating a sustainable-sound technology policy in transportation. These different theoretical complexities are combined to create a strategy for sustainability-oriented R&D and the implementation of technological innovations in transportation. The result of this strategy is the formulation of the concept of a `Window of Technological Opportunity'. Empirical results are presented for the case of fuel-cells.

SUSTAINABLE DEVELOPMENT AND THE IMPLICATIONS FOR THE TRANSPORT SECTOR

Worldwide, the transportation sector is characterised by strong growth. This growth is evident in both the transportation of passengers and the transportation of goods. Simultaneously, a shift is taking place from less polluting modes of transport to those that are more polluting, mainly caused by satisfying the increasing demands for faster and more flexible transport systems (Schäfer and Victor, 1996).
The negative impact on the environment is increasing as a consequence of this growth. Particular points of attention are the global effects (CO_2-emissions and NO_X-emissions), quality-of-life aspects and congestion. Other points that need more attention are the life-cycle effects related to the production and the recycling of vehicles caused by the introduction of production capacity in the Far East, South America in the short term, and in India in the medium term.
Because of this development, transportation's impact on the environment worldwide will increase both in the near future, and beyond. Considering the need for ecological sustainability, it is important that these environmental problems are given priority (WCED, 1987). From this perspective, it is argued that the transportation sector will have no alternative but to develop a sustainable transportation system (see for instance UNCED, 1992; E.U., 1993; EEA, 1995; Worldbank, 1995 and many others).

The technology card

Technology provides many possibilities to reduce the impact of transportation on the environment. However, its development and implementation involve several different complexities and, in relation to this, great uncertainties and risks. Therefore, implementation requires a clear strategy and a multidisciplinary approach. Important parts of a technology development strategy should be: a) distinguishing the right level of analysis (the transportation system as a whole, the level of modalities, passenger versus freight transport, etc.); b) insight in the process of implementation within the transportation sector; c) insight into the development of technological innovations and finally; d) the role of the several different actors in the innovation process.

Concentrating on the transportation sector, a distinction can be made between vehicle-oriented technologies and traffic management-oriented technologies (Gwilliam and Geerlings, 1992). Several studies indicate that especially technologies that are aimed at management (e.g. road-pricing, route guidance, enforced speed limitation, etc.) can be deployed in the short term. In terms of innovation, these technologies are in the implementation phase. These possibilities taken together will indeed contribute moderately successfully to reducing the impact on the environment, and they are aimed particularly at the non-global effects. However, because of the fact that a clear view on an implementation strategy is lacking, or this type of innovation is implemented wrongly or not at all, the results aimed at other environmental effects are disappointing. In the long term, better results for the environment will be achieved, by vehicle-oriented technologies (e.g. new modalities, alternative fuels, new engine concepts, etc.), particularly for those effects that have been rated a priority, such as the global effects and the life-cycle aspects. In this paper, this type of technology is called mega-technological innovation.
Mega-technological innovations are characterised as technologies which operate on the system level, or on a modality level, where the period of R&D is distinguished by protracted development, substantial uncertainties (risks) are involved and the area of application is global.

TECHNOLOGY DEVELOPMENT

It could be held that history has little to offer when it comes to the predictability of technological developments. Many books and articles have been published which have attempted to predict the future. Some of the authors, like Jules Verne, frankly acknowledged that they hardly used any serious methods. However, even scientific approaches have sometimes been completely inaccurate.
In 1920, the *Scientific American* printed an editorial predicting the future, based on the developments of the last 75 years. Although, in retrospect, that article seems to make strikingly accurate predictions, two omissions can be distinguished; none of the authors foresaw that only a month after publication of the article, radio telegraphy would be invented and neither did they predict that in the same year, sound would be added to films. Both developments were important breakthroughs in those days.
As early as 1900 a well-known futurologist like George Sutherland had predicted the rise of telegraphy, the wireless clock and recording apparatus, whereas he shut his eyes to aviation and space travel - that was stuff for dreamers and daredevils.
In 1937 the National Resource Committee in the United States published a report entitled: *Technological Trends and their Social Implications* (NRC, 1937). This report, that is still worth reading, sketches several technological trends which were predicted to happen in a number of social sectors, including the transport business. The Committee was wide off the mark when it predicted developments in aviation.
Future developments in transportation is still a fascinating topic, as the *Scientific American* published in 1997 again a special issue on expected developments in transportation.

Nowadays, there is more knowledge and insights into the process of technological developments and innovation. In current academic work this is the domain of *technology dynamics*. Technology is presently judged as a crucial factor in the economic performance of firms, nations and even supra-national organisations. Technology has become an essential factor in everyday life.
Several reports (EU, 1992a; U.S., 1993; MITI, 1992) estimate that a large number of potential innovations will emerge in the near future. A further analysis of the position of technology in society seems desirable.

The impression could easily arise that there was some confusion about how innovation processes occur, reflected in the dichotomy of opinions. A major integration, but also scientific breakthrough in the thinking on innovation theory took place in the work of Nelson and Winter (1977, 1982) and Dosi (1982, 1988). Nelson, Winter, Dosi and many others have, elaborating on the Schumpetarian theory, focused attention on the role that the social-cultural and institutional factors play in processes of innovation and diffusion of technology. The innovations of Schumpeter offered the opportunity to Nelson and Winter to not only undermine the dominant and prevailing opinion of neo-classical economists, but also extend the theory and understanding of technology dynamics.

Nelson and Winter observe that technological change depends on variation and selection processes aimed at solving technologically defined problems. These processes are not a-select or random, but clearly structured by formal and informal rules. There is a certain rigidity and inertia in the degree of change in technology, as a result of which the variation is not unrestricted. The presence of rules implies that technological development follows quite specific directions, while other possible directions are ignored. In this sense, technical change can be conceptualised as a constant succession of variation and selection within a certain framework. Nelson and Winter (1977) introduce for this phenomena the concept of a *technological regime*: the `direction of progress' of technological change. According to Dosi (1982), a technological trajectory contains the changes in technology which take place in the framework of a technological regime or *paradigm*. According to the thesaurus of the PC, the word `paradigm' means `example, ideal, model, pattern or prototype'. A technological paradigm or regime is defined by Dosi as a model or pattern of solutions of selected technological problems, based on selected principles derived from the natural sciences and on selected material technologies. In this approach there is the growing recognition that history counts. Past technological achievements influence future developments via the specificity of knowledge that they entail, the development of specific infrastructure, the emergence of various kinds of increasing returns, etc. In this context, it can be simply said that a paradigm is a prevailing rationality. The paradigm can be understood as the state of knowledge, skills and technology existing at a particular point in time.

The environmental challenge

The challenge will be, by using the concept of heuristics, to apply the innovation-trajectory idea *ex-ante* for the purpose of developing an environmentally-sound paradigm. The distinction between concepts derived from technology dynamics (incremental versus breakthrough technologies) is less relevant for transportation purposes. That distinction focuses its attention on a techno-centric approach, which does not address the complexity of the transport sector. The transport sector requires its own approach, which most emphatically needs to be linked with the classification based on the transportation sector's stratification.

A wide variety of interaction possibilities exists between the three complexities that are part of the 'sustainability triangle' (Munasinghe, 1993). This is partly positive interaction: thus the large-scale introduction of electric vehicles can be noted as a positive development for all the three goals connected to sustainability: economic, socio-economic and ecological. However, in most other cases where negative trade-offs come into play, the situation is considerably more complex. For this reason it can be concluded that technology can contribute greatly in bringing sustainability closer. Nevertheless, it is justified to warn against having too much technology optimism concerning technological solutions: there is simply no easy technological fix for the environmental problems caused by transportation.

THE ROLE OF GOVERNMENT AND PRIVATE FIRMS

How will decision makers deal with the uncertainties and in which way can the uncertainties be incorporated into a strategy aimed at sustainable development? The transportation sector has a number of specific characteristics that make the government's contribution indispensable. One of the most important reasons for this is that sustainability has to be considered as a collective responsibility. When dealing with sustainability's consequences for individual action, acquiring support from actors within the transportation sector appears to be a very complex problem. This makes the transportation sector one of the most difficult sectors to regulate when it comes to properly assessing undesired negative externalities. The problem is that manufacturers of transport modes, as well as the users of the modalities and participants in the economic systems, all value other objectives (e.g. freedom of action, individual economic and social objectives) more highly than the collective responsibility.
It is important that the government helps to accommodate this intractable dilemma. Supposing that the government is co-owner of the theatre, two roles can be distinguished, namely director and co-actor. The way in which the two roles are interpreted (effective, self-confident, correcting if necessary, facilitative, etc.) seems to be quite the opposite to the political and social mainstream in large parts of the world, which is in favour of a retreating and deregulating government as well as increased possibilities for free trade.

On its own, the government will never be able to attain its idea of sustainability. It is for this reason that great importance is attached to cooperation with other actors such as the private sector. Hence, the technology that is necessary for sustainability is largely being developed by the private sector, varying from multinational firms to very specialised laboratories that are already (to a large extent) used to cooperation. The industrial literature describes this phenomenon as 'entering into strategic alliances.'

Moreover, there has been a fundamental change in the position and responsibility of internationally operating companies. An increasing number of factors necessary for realising the two traditional objectives of the private sector, such as profit maximisation and continuity, have meant that these objectives now have to be seen in a different context. The private sector has come to realise that a company increasingly operates in dynamic surroundings, which, in order to secure these two traditional objectives, requires the company to excel in many different areas. Important new areas of attention, such as ethical responsibility and ecological responsibility, are rapidly gaining importance for the management of these firms. Because of the unpredictable nature of these risks, a leading company will anticipate in order to try to reduce these risks.

To a large extent, the government determines the boundaries of the playing field. As director, it can define the boundaries of the playing field. As co-actor it can also actively cooperate in realising these limiting conditions together with the other actors that have to meet these preconditions. This means the government has to adopt an approach aimed at cooperation. The notion of network management (Håkansson, 1987), originating from the science of public policy management, coupled with the deployment of a new generation of instruments, provides a good basis for a new approach. In the new approach, the dynamics of the market is highly appreciated as a mechanism because it can lead to realising `win-win' situations. It is also in the private sector's own interest to cooperate with the government within this approach, especially when it concerns determining the playing field for the medium and long term. This explains why identifying `fields of common interest' is important.
However, a policy solely based on making the most of exploiting fields of common interest situations will never yield sufficiently good results to be able to pronounce the policy as effective. It is for this reason that an adaptation of the policy is necessary, which will include a shift from (traditional) vertically-oriented instruments towards horizontally-oriented instruments based on uniting the several different parties (De Bruijn and Ten Heuvelhof, 1991).

The actual situation in the area of a sustainability-oriented technology policy shows very few concrete results. Many national governments do not feel capable of pursuing an active technology policy, while other governments are not willing to pursue such a policy and some governments have not yet even considered the possibility of pursuing any policy at all. This attitude can partly be explained by the fact that mega-technological innovations seem to develop autonomously within the international arena, causing a government to feel powerless. International organisations (e.g. the UN, the World Bank and the IMF) primarily seem to give priority to economic development.

Furthermore, the private sector is not really used to cooperation with governments in areas of sustainability-oriented technologies. Although a few examples of successful cooperation can be mentioned, these cases show that the private sector's common interest was mostly in the area of financial possibilities offered. In most other cases, the private sector usually considers government intervention to be a threat to a free market attitude.
This leads to the observation that negative external effects, on a global level, are insufficiently recognised, which means that it is all the more vital to have both a technology policy for global sustainability and an organisation which can ensure the achievement of this goal.

The paper considers the various complex ideas that have emerged from various scientific disciplines. Network management as well as strategic alliances appear to stand for a rational approach that makes everything look explicable and makable. This impression is deceptive (Contractor and Lorange, 1988; Porter, 1990). Within the rational process of technology development and technology policy the role of mankind as designer and developer of both technology and policy should be stressed. Development of technology not only requires the observance of scientific laws and rationalities, but it should also express the desirability of making technology serve society's purposes. It was mentioned earlier that the need exists for an attitudinal change in order to incorporate sustainability into the policy. Technology can enable the integration of all economic objectives, transportation objectives and ecological aspects that could possibly lead to the desired synergy. However, only humankind can realise this synergy. Attention for the normative aspects within the policy is called the `economy of touch' (see also Fukoyama, 1995). This self-confident approach can assist in stimulating a `belief system' and trust which could bring the objectives closer towards realisation. There is a good chance here for putting the concept of sustainability for the transportation sector into practice. A sustainable transportation system is to a large extent a matter of attitude.

Defining a `Window of Technological Opportunity (WTO)

In general, it can be observed that technological innovations evolve regularly from R&D processes, but their implementation encounters considerable difficulty. This especially applies to the transportation sector which has many examples of innovations that either have never been implemented or have caused undesired side-effects after implementation. These trade-offs lead to what the Dutch call *`De wet van behoud van ellende*' (`The law of the maintenance of misery'). An important factor causing this phenomenon is the fact that an insufficient amount of both insights and information reaches the decision makers. A well-organised technology policy (e.g. by establishing multidisciplinary teams that cooperate internationally) can contribute to the *ex-ante* steering of technology dynamics. The strategy's objective should be geared to making the Window of Technological Opportunity operational: a clear goal and a clear strategy for sustainability-oriented technologies.

Because the path towards sustainability is full of uncertainties, the technology policy aimed at sustainability should anticipate and limit these uncertainties as much as possible. Therefore, it is important to establish goals in advance. Research in technology dynamics indicates that a goal can be established by means of determining a heuristic. This paper specifies this by means of distinguishing an ecological heuristic. In this approach the heuristic stands for the transformation of the possibilities into fruition, as well as being aware of the limitations of technological innovations and the requirements that can be set on the basis of the concept of sustainable development.
For realising the heuristic, it is important to understand the processes of technology dynamics. These are processes of variation and selection, feedback mechanisms, acceleration and deceleration, involvement of multi-actors, changing interests and perspectives, etc. Conscious steering of this process towards goals that are based on sustainability (heuristics) contributes to the realisation of the Window of Technological Opportunity.

Characteristics of innovation processes for sustainability-oriented technologies in transport

A study of the literature shows that a number of requirements can be formulated regarding the technology policy for realising the Window of Technological Opportunity. These are partly general requirements, originating mainly from the public administration theory about network management and from the business administrative theories on strategic alliances. In fact, these are requirements that can address any policy or management issue.

Table 1 - General strategy requirements

General strategy requirements
· Robustness
· Prioritisation
· Flexibility
· Coherency, consistency, integrity
· Transparency
· Reliability, trust

In addition, specific requirements originating from perceptions of technology dynamics need to be formulated. In a way, these requirements can be considered as preconditions for a technological innovation process. Such specific conditions are:

Table 2 - Technology policy requirements

Technology policy requirements
· Clear mission statement
· Identification of participants/Identification of `Fields of Common Interests'
· Explanation of responsibilities of different actors
· Embodied in - or not in contradiction with - the existing policy framework
· Anticipation of long-term perspectives (trends)
· Identification of correct Level Playing Field
· Well-defined relationship between strategic partners
· Identification of correct implementation level in the transport sector
· Selection of policy instruments
· Respecting innovation delay

The above-mentioned aspects are not certainties or guarantees for successful strategic operating. Until now, however, several of these preconditions have been met only intermittently. Especially in situations where the policy is being steered *ex-ante*, directed at abstractions such as the concept of sustainable development, it is important to take into account these aspects in a systematic way.

Realising the Window of Technological Opportunity

Meeting all criteria listed in Tables 1 and 2 is part of realising the Window of Technical Opportunity. In this way, the WTO includes both a static (policy conditions and heuristic) and a dynamic element if the strategy is followed in mega-technological innovation processes. The seven steps that are distinguished in the strategy should therefore not be considered as consecutive phases. Several steps may be taken simultaneously. Delay, setbacks and unexpected opportunities are all frequently occurring characteristics of the innovation process. This implies that in addition to the process as such, which will be dealt with below, the organisational aspects need to be discussed.

Seven steps for realising the WTO were identified. The background and structure of these steps are explained by Geerlings (1999).

Table 3 - Technology policy strategy

A strategy for governmental action	
· Step 1	Identification of sustainably-sound heuristics
· Step 2	Defining the relevant `communities'
a	*The identification of the level playing field*
b	*The composition of the strategic consortium*
c	*The responsibilities of different actors*
d	*The incorporation in the existing policy framework*
· Step 3	Anticipation of long-term perspectives
· Step 4	Assessment of technological potentials and limitations
· Step 5	Identification of the `Fields of Common Interests' (F.C.I.)
· Step 6	Application of instruments
· Step 7	Identification of the "Window of Technological Opportunity"

As has been mentioned before, the process of change is at the centre of the above-mentioned approach. The WTO, therefore, should primarily be considered as a perspective that can guide the formulation of a technology policy for the transportation sector which is aimed at sustainability. It is on no account a prescription that, if all preconditions are met, will *automatically* lead to success. That is not, and cannot be, the pretension of a strategy. What it will do, however, is contribute significantly to a reduction of uncertainties as well as steering the desired project results.

THE FUEL-CELL EXAMPLE

In this paper, the cases of the Fuel-Cell (FC) technology is dealt with, which is a technology being developed as a technological innovation to be implemented in the transport sector. The case relate to a possible future development, which may become of the utmost importance to a transportation sector aimed at sustainability. The case will now be evaluated in terms of to what extent they comply with the conclusions drawn from the pervious (theoretical) sections.

A mega-innovations

The selection of the 'Fuel-Cell technology' was based on the characteristics of the innovations (such as their lengthy development trajectory, etc.) which all comply with the characteristics of a mega-technological innovation. If it is being steered correctly, the innovation should lead to a more sustainable transportation system. However, there is a substantial risk that, because of the lack of a clear implementation strategy, the promises cannot be fulfilled, as was the case with a large number of transportation innovations in the past (e.g. the turbo charge).

The FC technology, based on an electrochemical process, by which electricity can be generated through transformation processes, can be characterised as an enabling technology. This means that the technology was originally developed for other uses and has only been employed at a later stage in the transportation sector. 'Moving perspectives' is therefore a central notion in the historical analysis of the FC's innovation trajectory. The FC technology is employed within the system made up of the various modalities (Ballards, 1992).

Research has been made into the extent to which the cases comply with the general conditions for the technology policy. In summary, the outcome of the analysis is presented in Table 4 below.

Table 4 - General strategy requirements for the two empirical cases

	Fuel Cell-technology		
	United States	**Japan**	**European Union**
· Robustness	+/–	+	+/–
· Prioritisation	+ (+)	+	+
· Flexibility	+	n.k.	+
· Coherency	+	+	+/-
· Transparency	n.k.	n.k	+
· Belief system	+	++	+

n.k. = not known

Within the FC-technology cluster, a relatively large number of aspects are still unclear (ADL, 1995). Generally, however, it can be argued that the question of to what extent the general requirements are met can be answered in a (moderately) positive way.

Subsequently, the extent to which the innovation comply with the specific demands of the technology policy has been analyzed. These requirements are embodied in the strategic framework. Table 5 below illustrates to what extent the items in the framework have been complied with in relation to the strategy requirements.

Table 5 - The strategy framework for the case of Fuel-Cell Technology

		Fuel Cell-technology		
		United States	**Japan**	**European Union**
1	Identification of sustainable-sound heuristic	++	+	+/–
	Defining `communities'			
	a Identification of level playing field	++	+	+
	b Composition of strategic consortium	++	+	+
	c Responsibilities of different actors	++	+	+
	d Embodied in policy framework	+/-	++	+/-
3	Anticipation of trends	++	++	++
4	Assessment of technological characteristics	+	+	+
5	Identification of the `F.C.I'	+	n.k	+/-
6	Application of instruments	+	n.k.	-

n.k. = not known

This inventory shows a large diversity of valuations. It is noticeable that the FC-technology is developing in a positive way. It is particularly noticeable that the FC development is completely in keeping with the expected developments (public policy perspective, business perspective, environmental perspective and transport perspective).
For the rest, it is noticeable that, despite the diversity of valuations and a large number of uncertainties, the strategies that are followed are generally assessed positively. A marginal comment that can be made relates to the E.U. policy (and that of its individual Member States), which is valued in a less pronounced and unanimous way than the U.S. policies and Japanese policies.

Synthesis

Generating a Window of Technological Opportunity.

The question is: To what extent this innovation develop in relation to the WTO-strategy? It has been shown that on purely technical grounds, the innovation can contribute substantially to a more ecologically-sustainable transportation system (see Geerlings, 1999). However, an essential condition is that the technology must be positively steered in this direction, because otherwise there is a serious risk that it will lead to an undesired unsustainable development.
The FC-technology is developing more favourably from the WTO-perspective. The points of attention distinguished in the strategy framework are all to a greater or lesser degree dealt with in the policy pursued, although there is no universal strategic vision. The environmental heuristic is one of the driving forces for the research efforts, and explains why this project is obviously concerned with a process of a *technology pull.*
Emphasis has to be placed on the distinction between the developments in the U.S. and Japan, on the one hand, and the policy of the individual E.U. Member States and the communal policy of the European Commission, on the other hand. The U.S. pursues a clear and consistent policy concerning both the general policy and the technology policy requirements. These characteristics are found far less prominently at the E.U. level or at the level of its Member States. As regards the Japanese policy (Ohmae, 1989, unfortunately there is insufficient information available about all relevant aspects.

For realising both the FC technology, the approach that has been suggested for creating a Window of Technological Opportunity seems to be a promising way to provide strategy support for sustainability in the transportation sector. Moreover, the concept makes clear exactly what the risks are that play a part in realising this objective.

The `new' role of government.

The case challenge the government's new role. It is noticeable that in the two cases, all governments concerned are already playing a more active role than merely facilitating R&D. Nevertheless, there are a number of significant distinctions to be made between the cases.
Among the positioning of the various governments in the development of the FC-technology are remarkable. The national governments that are involved in the various alliances that operate internationally are operating in overlapping alliances. Therefore, the governments are less directly involved and have less interest in the development of the technology. It is interesting to see that the rivals are all focused on the opportunities of success for a specific type of fuel-cell and not on competition among partners and the governments themselves.
The FC-technology fits in well with the pursuit of sustainability (IACT, 1996). There are indeed still a number of uncertainties, such as the life-cycle aspects of the FCs and the energy-input (with their subsequent possibly negative consequences). However, as the FC-technology will be integrated in the existing transport system (thereby primarily focusing all attention on road traffic), the rate of success regarding implementation is considered to be very high. The question which energy input will be used is an important but still uncertain factor. Requirements will differ for the production and distribution of H_2 on the one hand and of ethanol, methanol or LNG on the other hand (Williams, 1993).
From the government's position it is recognised that the complexities surrounding the FC's R&D can only lead to an initiating and facilitating (pro-active) role for the government. The approach of the FC-technology fits well in the structure of the strategic alliances that operate on an international basis; new global networks are under development which have opportunities for regional specialisation. However, the highly fragmented activities and support measures of the various governments are a less positive result of this. Nevertheless, as environmental-technological innovations will be playing a major part in the future, large-scale implementation of the FC seems very promising (Kelly and Williams, 1993). Moreover, the case is already notable in the extent to which public-private partnership and outplacement of the R&D-activities have been organised.

The environmental heuristic is already playing a major role in the development of the FC. Here too, the risk-evading attitude is a decisive condition for successful implementation. This is mainly due to the signal that the Californian Government sent out with their Clean Air Act. For the FC-technology, this is no surprise, as the basis for the project, including the public-private partnership, has its origins in this stringent environmental legislation (US-DOE, 1993). At the same time, this illustrates the importance of a government that determines the (level) playing field in a clear way, while at the same time promoting cooperation among the various actors by means of horizontal instruments.
In the next phase, a shift will take place from fundamental research and demonstration projects to large-scale implementation. It will be clear that the notion of network management and the use of instruments will again be on the agenda.

At various administrative levels, the necessity will arise for a clear organisation and strategy to implement technological innovations in the transportation sector in a sustainable direction. To this end, the concept of the Window of Technological Opportunity will serve as a major support.

EPILOGUE

The development of the Window of Technological Opportunity is a rational method for steering technological innovations in a sustainable direction. Although the WTO cannot be presently tested by empiricism as only two cases have been involved in this research, an answer to the formulation of the problem has taken place indirectly. Looking back, but also, more importantly, looking forward, a number of observations can be made that are to some extent based on the theory of empirical analysis.

Firstly, a major observation is the fact that sustainability is a normative concept. Numerous scientists have demonstrated that, based on solid scientific research, a fundamental change in our behaviour needs to take place in order not to hazard the ecological values in our world. Justification for this study can be found in the recognition that sustainability is necessary. However, sustainability can only be obtained if society is prepared to make choices and if individuals are prepared to accept the consequences, both for their own actions and for the mobility issue.

In this approach, of all factors, special attention needs to be paid to mega-technological innovations as these play a major role in bringing closer to implementation within the transportation sector, those innovations which are aimed at sustainability. This has to take place without cherishing the illusion of a `technological fix': mega-technological innovations cannot alone solve the problem of the environmental burden caused by transportation. As a consequence of this, we see in practice that in the first instance technical-economic arguments have acquired more significance in the valuation of the project than the environmental aspects.

One point of attention which has been undervalued in the implementation of the innovation strategy within the transportation sector is the complexity of the `levels of action' (global, national, etc.), the various levels of analysis within the transportation system (system level, modalities, etc.) and the valuation of the various environmental effects (global, non-global, life-cycle aspects, etc.). Analysis of the innovation process as a process which develops within a shell of general and specific preconditions, making use of presupposed (sustainability) heuristics and characteristics of the transportation sector, may contribute in a constructive way to an innovation strategy aimed at sustainability.

Currently, the visions of the government as well as of the internationally-operating private sector have a number of shortcomings. These shortcomings are to be found in their commitment to sustainable development (as a common interest), the individual roles that the actors can play in realising a technology policy aimed at sustainability, and the use and effects of instruments in order to attain the desired objectives.

Clear criteria for setting priorities in relation to trade-offs within the `sustainability-triangle' are lacking. Emphasising the necessity for a fundamental attitudinal change of the decision maker may therefore only lead to a voluntary attitude. In addition, ecological aspects, an essential part of the concept of sustainability, are in danger of fading into the background if barriers have to be overcome concerning the choices that need to be made.
Identifying a number of steps in an innovation process is therefore a way to continuously monitor the process to check that it is constantly focused on sustainability, although reality can hardly be fragmented into precise steps.

Attention for the psycho-emotional elements in the `rational' steering and selection process of technological innovations in the transportation sector (such as realising the importance of the `economy of touch' and stimulating a `belief and trust-system) is something that has hardly been recognised to date.

Governments, on both the national and international level, have only limited knowledge and understanding regarding the fact that new technological concepts definitely need steering in order to achieve a sustainable transportation system. It is very often *a priori* assumed that innovation trajectories develop autonomously.

What is lacking is a clear and acknowledged platform that brings out into the open the urgent need for a sustainable transportation system. As a consequence, there is only poor communication not only among the governments themselves but also among governments and other actors, such as the private sector and social groupings, concerning the objectives which are to be pursued in connection with a sustainable technology policy.
Besides the steering of technical developments in a sustainable direction, it is still very unclear exactly what the strategy for a sustainable transportation sector in the medium and long term will be.

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