DTU Library

# A challenge for management and recognition

**Borup, M.**

*Publication date:*
2001

*Document Version*
Publisher's PDF, also known as Version of record



*Citation (APA):*
Borup, M. (2001). *A challenge for management and recognition*. Abstract from REMAP Workshop, Hillerød, Denmark.

REMAP workshop, September 2001: Academic research management in the Triple Helix

# A Challenge for Management and Recognition

Mads Borup, Technology Scenarios Programme, Risø National Laboratory1

The changes in the processes of knowledge production and knowledge handling we experience in these years, are deep and of significant character. The identity of what objects of scientific knowledge are, is itself changing in these processes. Research and construction of scientific and technological knowledge are increasingly an explicit issue of strategic planning, regulation and management (van Lente 1993). What is recognized as valuable and trustworthy knowledge is never a simple question. It is always complicated and can only be accounted for through descriptions of the cultural/discursive and institutional context in which the knowledge objects exist. It is situated knowledge (Haraway 1991, Suchman 1989). Research, knowledge development, and knowledge use are therefore also a question about actors and networks and alliances between actors.

In a knowledge society where knowledge is developed and repeatedly re-translated in local settings, often closely related to its application (Gibbons et.al. 1994), managers of research are not only managing institutions and processes of given knowledge objects and facts. They are themselves participants in the creation of the facts. This is both the case at the level of individuals and at the level of individuals. Similarly, scientists carry out management interactions. They deal with strategic, organisational, and institutional aspects of science and research. Generally speaking, the integration of knowledge and strategy makes the emerging knowledge society a challenge for both processes of management and recognition.

This paper, which empirically is building on a study of university science in the area of

1 The study behind this paper was carried out at the Department of Technology and Social Sciences at the Technical University of Denmark. (The department is now a part of the new Department of Production and Management). The project was funded by the Technical University.

acoustics and sound technology over a 10-year period, deals primarily with the last of the two mentioned issues: From the scientific activities in the area of acoustics, the paper shows examples of how scientific practices include managerial and strategic aspects and how management and scientific facts are closely related and integrated in each other. The managing actions of scientists appear internally within scientific communities and research groups as well as in the interaction with actors outside scientific institutions. The managing interactions contribute to the creation of direction, goals and problem understandings within science. They also play an important role in involvement of additional resources in the research activities and in the information and alignment of actors in accordance with the understanding within science.

That research and knowledge processes are situated activities carried out by actors in specific contexts, also indicates that there are differences between different areas of academic research. There exist different epistemic cultures (Knorr-Cetina 1998 and Conference on "Epistemic Cultures and the Practice of Interdisciplinarity", Trondheim 2001). And the heterogeneous set of actors and institutions that are involved is not the same from one case to another.

On the one hand, it is clear that there is nothing especially non-human and de-socialized in an essential sense, about natural and technical science (Collins 1992). Research is not of a completely other, or more pure, quality than other human activities. On the other hand there are parts of the discourses, practices, heterogeneous sets of values etc. including their mutual relationships that are special and more or less general for research activities. Especially, if you look at activities in specific sub-areas of academic research. E.g. technoscience, which in academics is a major sub-area of the universities, is characterised by a.o.t. the two important and related value norms of creating new knowledge and new technology.

But even also within a specific area of research the set of actors, the organisation of the processes etc. often vary and are not the same from project to project. The relations between the many heterogeneous elements involved in scientific processes are not static but dynamic. Within studies of technoscience and engineering the heterogeneous character ('heterogeneous engineering', Law 1987) of innovation and knowledge development has been pointed out:

"… a successful engineer is not purely a technical wizard, but an economic, political, and social one as well. A good engineer is typically a 'heterogeneous engineer." (Bijker 1995, p. 15)

The management dimension of research and knowledge processes varies as well, both between academic areas and within the single area, and a simple model for what research management is and should be is not adequate.

## Some central issues in acoustics in the late 20th century

The two Danish acoustics science groups in my study are in the late 1980th and in the 1990th occupied with new ways of making artificial sound; that is ways of improving the possibilities for doing life-like record and playback of sound and ways of modelling sound on computers. Simulation of sound through extensive computer calculation is increasingly becoming a research issue in these groups as well as in the broader cross-national acoustics community of practitioners. Many research groups in the field are at that moment inscribed in the discourse of computer simulation and enhanced possibilities through extensive computer calculations. In the cross-national communities of practice, which primarily is a North European and North American network, the Danish groups often play a central and identity-creating role.

One of the groups is working with computer simulation of sounds in rooms. They are concerned with problems about the acoustics of rooms and with techniques for numerical modelling these sounds on a computer. A figure illustrates some of the elements in the conceptualisation of sounds in room. The sounds are modelled like a number of rays, sound rays, going around in the room. The sound rays end at a *listener* in the room. The figure also indicates which kind of rooms the scientists are dealing with: Concert halls, theatres, auditorium and other rooms where architects, building owners and building constructers find the acoustic qualities of the room important. It is relatively large rooms, and it is rooms that are in a projecting phase and under construction. It is not all room and spaces the scientists include when they say 'room'.

The groups of acousticians are located at university institutions and consist typically of a couple of scientists. Funding from national research programmes is one of the typical sources of money for the research.

I have studied the processes of the technoscientific research groups through a case study approach. The empirical work consists of primarily qualitative research interviews and study of the large amount of texts that are involved and developed in the activities. The interviews have been with the scientists and with actors that in the interaction processes are related to the activities. These are e.g. industry representatives, technology users, and colleagues in the international community of practitioners in the field of audio technology and acoustics.

**Example 1**

The first situation from these activities I will draw your attention to is in fact three situations, or three interactions. They happen in the same period of time; in the same weeks and months in 1989-90.

For some years the scientists at this acoustics laboratory have had a close contact to a group of six Danish consultants and consultancy companies working with room acoustics and with planning and design of rooms. The consultants are interested in using a sound simulation computer program in their work. Both at the consultant companies and at the university have work been done to make a computer programs that can calculate the acoustical quality of a room that is not built yet.

At this point around 1990 a new institution is created. The new institution is a *partnership* (‘interessentskab’) where the consultants are the members. The partnership is a binding agreement about sale and use rights of the room acoustical programme that is developed at the university. The programme is ready to be sold and used. Further developments of the user interface and routines for calculation of a few additional secondary, derived parameters shall be made in the time to come. The university laboratory appears in the partnership agreement as those who shall do the developments in the program. Funding of the further development of the program can come from the partnership. The name of the partnership is Acoustium I/S. The room acoustical programme is also named Acoustium.

The partnership is a very unusual kind of organisation in connection with university research. Though not one of the members of the partnership, one of the scientists is the central and driving actor in the construction of this new institution. In the network with the consultancy companies he is the leading person carrying out most parts of the managerial developments and planning.

With this institutionalisation, the relations between the consultancy companies and the science group is formalised and made closer. And the roles of the different actors are made clearer. In addition, the problematic aspect, there is for a public research institution like the university in carrying out a commercial sale of the developed technology, is handled with the partnership.

<u>Interaction 2</u>

In the same period in 1989-90 the research group applies for funding from the national research council. The scientists propose a project that shall make it possible to do *audible simulations* of sounds in rooms. Instead of just getting numbers and figures as output of the computer modelling, the objective of this research project is to construct a technological system that enable actual listening to the simulations of concert halls etc. with your ears.

A key argument for the feasibility of this aim is that the scientific group earlier has developed a well-functioning room acoustical computer calculation program, which the audible sound simulations can build on. The situation is that the theoretical and practical knowledge about how to do computer modelling of sound in rooms exists already. And because of that it is now time to pursue a goal of making the simulations of sound in rooms audible.

“The main goal: to make a realistic sound simulation of a room by computer calculations can be reached through incorporation of a number of new facilities in the existing ray tracing model.” (Application 1989, project description p. 3, my translation)

The technology that can make the simulations audible, the *auralization* unit, which it is later called, is simply a supplement and an add-on to the existing room acoustical programme. The computer program is a basic prerequisite for the proposed research project.

It is the idea of the scientists (including the driving person mentioned above) to put up this research project. The goal of making the simulations audible is not expressed by the collaboration partners/technology users in the group of consultants. The close contact to the consultants is in connection to the research application a legitimating industry relation. In addition the consultants have the role of an easy way to get the new knowledge and technology tested. The university laboratory gets the funding for the project from the public research council. The project period is a couple of years.

Interaction 3:

When the scientists soon after, and while the negotiations about the partnership institutionalisation are taking place, begin the laboratory work in the project funded by the research council, the subject is not audible simulation. The science group want to construct a new room acoustical computer programme.

They do not believe in the earlier developed computer routines and programme. The calculations with the earlier program are not right; or at least they have some serious and substantial sources of errors due to limitations in the employed calculation principles. The researchers have to consider new basic calculation principles and do theoretical and practical experimenting with other ways of modelling sounds in rooms. The internal working papers and the later written scientific articles concerning the work in this period are not dealing with the problem of making the computer calculations audible (Nilsson 1993 a.o.). The scientists also have to make distance to the earlier developed calculation programme and routines because of a controversy about rights (copyright etc.) with a scientist formerly working on the model development.

The science group develop a brand new calculation model. In connection with this, the science group investigates what other science groups in the area have developed of knowledge and are working with. Through the arrangement of an international workshop, the Danish group manage to be a central actor in the creation of identity and direction in a cross-national community of practice in the area.

| Situation 1 | Situation 2 | Situation 3 |
| --- | --- | --- |
| Institutionalisation<br>Partnership | Research application: Project on audible simulations | Laboratory work and scientific community interactions |
| The room acoustical programme exists.<br><br>Ready to sell.<br><br>Shall be further developed:<br>Improvement of the user interface.<br>Add minor details in the presentation of calculation results. | The room acoustical programme exists<br><br>Ready to use<br><br>Add on:<br>Audible simulation | A working room acoustical programme does not exist.<br><br>A radical new and realistic computer model shall be developed.<br><br>Radical new principles of calculation and scientific findings.<br><br>(Not audible simulations) |

The point is here that the three situations take place at the very same time in a research group's activities. The example is of cause chosen because of the clearly radical character of the multiple appearances of the scientific object: In one situation it is a fact that the object exists. It is a scientific fact and it is a ready-to-use technology. In the other situation the object does not exist. It is exactly what which takes place at the very same time.

What is in the centre of the research changes more or less from situation to situation. And what is considered the core, the 'hard core', of the activities is not the same from situation to situation. There are multiple representations. Does the technological object, the sound simulation program work or not? Both!

Even though the existence of a computer calculation is changing from situation to situation, it is a solid heterogeneous network of actors that the scientists have managed to build up. Support is gained from both the broader academic community of practice, from industry and from the state.

The contradiction about the existence or not of the knowledge and technological object does not make the research activities significantly weaker. An understanding of scientific facts as hard and objective in them selves cannot account for what is happening here. The recognized facts are instable, have changing and multiple appearances, and are influenced by the local situation and context.

**Example 2:**

The second example is about an interface that did not come true. It takes place a couple of years later.

The group of scientists communicate with other scientists. They have presented their work on computer modelling of sound in rooms to the other acousticians. And they also know about the activities of many other acoustics laboratories primarily in Northern Europe. Especially, there is a close contact to an acoustics laboratory at another Danish university. Scientists at this laboratory have started to work on improvements of *artificial head recordings and playback* and later also on simulation of artificial head sound signals. An artificial head, or a dummy head, is a mannequin with microphones in the ears. The microphones are located at the eardrums.

The idea in this kind of system is that the two signals from the eardrums, or from the microphones at the eardrums place, are enough. The two signals are all that is needed to give a complete audio impression to the listener, including all spatial and directional information. If the two signals are transferred precisely to the listener’s eardrum, then sounds from sound source in all possible directions (behind, above, below, to the left etc.) can be reproduced.

It is the understanding in the two Danish research groups that their activities on sound simulation are related and that they mutually can benefit of each other’s work. The fruitfulness of the relation between the two groups work on sound simulation is e.g. mentioned in research applications and project descriptions.

At a conference in 1991 with participants from Europe, US, and Japan, one of the scientists from the artificial head research group suggests an interface between simulation of rooms and simulation of heads/ears in the technological systems. Through a standardized interface with a clearly defined and structured data communication between the two sides, a possibility of combining any room simulation technology with any head simulation technology is ensured. At that time very few, if any, of the developed computer models of sound in rooms have been used and tested in combination with simulations of heads and ears. The Danish scientist points out that this is a problem and that the solution is to make the communication possible through the employment of the interface standard. With the interface the structure of the simulated reality is specified with a distinct and objective border between room and the listener's head.

According to the Danish scientist, the interface gains support from the other science groups gathered at the conference, that is, from the leading science groups in the field. In the following months the details of the interface is developed. Data format, communication protocols, conversion routines etc. are specified. In an article in a scientific journal it is documented that the interface is feasible and will work (Hvenekilde 1993).

The interface clearly reflects the two Danish research groups and the division of labour between them. The group working with artificial heads and the two-channel binaural principle is at the head side of the interface and the group working with room acoustical modelling is at the room side. To the room modelling group, a successful connection with the head simulation technology is an important step that can fulfil the promises in their research council funded project about making the sound simulations audible. The technological object of the interface is a structuring of important parts of the communication between the groups. This shows that organisational aspects of the scientific processes are integrated with the technical.

The Danish research groups develop their activities further in direction of the interface standard after the interface has been announced at the conference. They undertake a series of meetings to plan and discuss the integration of their technologies. They investigate what shall be done to make the technologies communicate with each other and sketch out routines and subprograms that shall adjust the existing programmes and data formats to fit the interface precisely. In applications for more funding from Danish research council each group carefully avoids asking for money to activities that are at the opposite side of the interface and 'belong' to the other group. Instead they recommend the work of the other group. The strategic alliance between the two science groups is elaborated with the interface standard. It is a step in direction of further integration and coordination of the sound simulation activities of the two groups. Foreign scientists consider the integration of the technologies and work of the two Danish groups a very promising and powerful step.

To sum up the situation, the proposal of the interface is a suggestion of a standard for delimitation of objects (the room and the head; and the technological modelling there-of) and for communication and interaction between these two objects. It is an objectification of the objects of the scientific work. The interface standard is put up to avoid wasting resources on room simulations and head simulations which cannot fit each other and to make other institutions and persons working in the field align themselves to the understanding in the Danish science groups. As well as an objectification of the rooms and heads involved, it is a strategic structuring of the work in both the two Danish science groups and in the broader cross-national community of practitioners. The strategic and cognition aspects are deeply integrated and cannot be separated.

Problems:

But the interface never comes true. Or at least it has not come true yet, here nearly 10 years after its suggestion. The interface has not become the standard it was meant to be within sound simulation, even though it was considered a well-established fact by leading scientists in the area and the function is documented in scientific texts. The Danish research groups never did succeed in making their simulation technologies work together.

In the beginning the scientists work with enthusiasm on the integration of their knowledge and technology through the interface standard. But unexpected problems arise and after some years of investigation and negotiations between the two groups the integration of the technologies is given up. And the interface standard is not employed by other science groups.

The problems in the Danish activities among other things concern the time dimension in the simulations and about where to make compromises in the calculation accuracy. In the scientific processes the two groups stick to different key elements and focus areas in which they cannot and will not make more simplifications than they have already done.

Though the scientific findings and facts are about rooms and heads in general, the more or less implicit focus on specific (kinds of) rooms and on specific (kinds of) heads in specific situations has important influence. E.g. the room acoustical calculations are deeply integrated in the world of room acoustical consultancy and room acoustical problems having to do with large rooms. As mentioned, the simulated rooms are typically concert halls, theatres, and auditoriums. In this area, the acoustics of a room is characterised by decay time, clarity and other parameters that are described in different frequency areas. Recommended values of the different parameters to e.g. a concert hall for classical music is defined in the same frequency system. Similarly, the acoustical qualities of different materials and absorbers that are used for acoustical design of rooms, are described in this frequency terminology. In practice no feasible alternative to this exists. The room acoustical simulation research is structured by, and bound to, the area of room acoustical design work in which the technology is used.

The artificial head science group has similar local qualities implicit and explicit inscribed in their knowledge and technology. The artificial head activities cannot be adequately formulated in the frequency domain terminology.

Even though scientists both within and outside the Danish groups agree that in principle it can be done, it is not possible in practice. The interface border between heads and rooms in sound simulation turns out to be less feasible than proved.

As analysts of scientific processes, we must be very careful not to believe that we understand the processes better than the practitioners in the field. But I will suggest that the serious disagreements and fierce discussions and mutual accusations about breaking agreements, are not primarily a matter of different personalities. Instead it is a matter of objectivism and too much believe in the scientific objects as general and universal, and not bounded by the local settings in which the objects are developed and diffused. Under the powerful and to some degree dominating discourse of objective knowledge, the actors have no other explanations to turn to than personal aspects and disagreements in personal ‘chemistries’. But in many other situations, the same persons have been able to work together, and an explanation of the problems primarily in personalities is not sufficient.

This is also the conclusion the scientists come to some time after the fierce disagreements and the simultaneous breakdown of the collaboration between the science groups and the interface artefact. They have found out and recognized that the well-documented interface artefact was not as objective as it first seemed. Instead they understand it more as a strategic effort and experiment to try to put together the two otherwise separate areas they are working with, room acoustics and record & playback systems. After the disappointment of the interface that did not come true, the next step is not to give up the scientific work and loose most confidence in scientific capabilities. In stead it is to put up new strategies for the work and to find out new collaboration partners that can support and use the knowledge and technology developments of the group. As the feasibility of integrating the technologies of the two group has been a key element in the understanding and organisation of the research up until the breakdown, the strategic and organisational changes that are needed are also significant.

**Increase in management competences**

According to the studies of the two cases in the area of acoustics and sound technology, scientists and science institutions carry out managerial actions as part of the research processes. The managerial actions are many and of a large variety of types. The examples above show that both organisational aspects within the science group including strategy creation, goal-setting and problem definitions, construction of new institutions, and external aspects such as getting resources inscribed in the activities and setting up visions which engage other groups of actors.

The strategic and managerial actions are often complex. They are not simple. They structure the relations between many different elements of heterogeneous character, both technical, organisational, social, cognitive, economical etc. in complicated networks. Even though the strategies and management activities are not always successful, they are in many cases of a character that demand deep insight and experience in the area. They are not likely to be carried out on the basis of simple or one-dimensional assumptions about the area of work.

Both examples show that what is considered facts and realities do not stand outside the managerial and strategic aspects, but is integrated with them. Much of the knowledge which the experienced actor has e.g. about the power and limitations of different is more or less implicit and non-articulated in most situations.

This makes it a hard time to be research manager. You cannot understand the knowledge objects as stronger and harder than the actors that are supporting them and are aligned according to the inscribed understanding of the world. The borderline between visions of the future and existing, proven and working objects and facts is not a clear cut.

At the same time, managers of knowledge processes and research are participants in the creation of the scientific and technological knowledge, and not only innocent mediators, supporters, and decision makers acting with a number of ready-made knowledge objects and areas.

Analysts as well as managers of knowledge and technology must recognize and be aware of the changing character of knowledge, and of the fact that technoscientists and engineers are acting managers' role as well as the role as creators of technological artefacts and knowledge.

On the one hand analysts and managers of research processes must be aware of the strategic character of scientific facts and statements. On the other hand, the analysts and managers will be of most use, if they take in to consideration the situated character of scientific knowledge and do not limit themselves to the solution space and set of actors that is defined by the problem setting in the communities of practice within science and engineering.

A further point from the empirical study is that the managerial competences of scientists are increasing. There are clear indications in the study that the technoscientists since the mid-1980$^{th}$ in general have become more and more aware of the managerial and strategic aspects of the research and knowledge processes. They handle them more masterful now than earlier.

And the traditional natural science ideal within engineering and technoscience seem to be loosing some of its' strong power.

E.g. technoscientists increasingly accept a role in a techno-economical system where collaboration with industry and economical exploitation of the scientific activities are a central element in the set of values.

A related element in the increased strategic capabilities of science is the awareness of the present power of the discourse of change and development relatively to stability and tradition. Discussions and judgements about technoscientific activities both outside and within science are focused on what the activities will bring of new knowledge and technological objects in the future. It is more about knowledge and technology can do in the future than about existing knowledge and what technological objects do today. Most often the visions of the future are seen as positive changes. This is e.g. significant in descriptions of science and technology in the Danish mass media (Analyseinst. f. Forskn. 1998/99).

An example of how this is handled in the cases of the acoustics groups is the systematic demonstration activities that are carried out. The research activities and the technology that are under development are demonstrated at exhibitions, at conferences, and in connection with visits of groups of laypeople and professionals at the laboratories. The texts, sound examples, and graphics are carefully chosen in order to give the best and most engaging impression of the research activities. The demonstrations tell you a story about the future technology and guide you in your understanding of the sound clips etc.

The demonstrations are not just a look over the shoulder of the scientists at an ordinary work day. Special demonstration artefacts e.g. demo CDs and installations of systems with special designed headphones and capacity of many listeners at a time, are constructed. The demonstrations are in them selves carefully designed artefacts.

The managerial activities challenge the traditional understanding of scientific knowledge as objective hard facts. The examples from the empirical study shows that the management actions quite often are connected with controversies, unexpected surprises and confusion in the scientific activities. This indicates that usually scientific objects are not as stable and unambiguous as they seem at first. Instead they appear in multiple representations. Visions and expectations about the future are more or less implicitly integrated in the research activities and settings. And they are inscribed in the technological artefacts.

**Alternative to objectivism/positivism**

In accordance with the understanding of knowledge processes in (Gibbons et.al. 1994), it seems, as mentioned, that the influence of the traditional natural science ideal image in technoscientific activities is decreasing. A more adequate understanding of scientific and technological facts than objectivism and positivism is needed.

A better conceptualisation of research and knowledge processes can be given by employing the perspectives of situated learning processes in communities of practice and of experimental processes of generalisation and standardisation of objects (Lave & Wenger 1991, Latour 1993). This will account for the more experience-based character of scientific knowledge and artefacts. The contrast between implicit (‘tacit knowledge’, Polanyi 1966) and explicit knowledge can better be understood with this framework. Studies with this approach will have focus on the meaning of the involved socio-technical ensembles and the institutional and organisational aspects. The concept of boundary objects (Star and Griesemer 1989, Fujimora 1992) fit this framework and is especially fruitful in accounting for simultaneous developments technological/scientific objects and networks between actors and institutions.

## References

Names of institutions and persons from the empirical study are made anonymous both here in the reference list and in the text above.


Analyseinstituttet for Forskning (1998/99): **Aviser om forskning** (‘Newspapers on research’)
Bijker, Wiebe (1995): **Of Bicycles, Bakelites, and Bulps - Toward a Theory of Sociotechnical Change**, MIT Press, Cambridge
Callon, Michel (1991): **Techno-economic networks and irreversibility** in [Law, 1991] pp. 132-161
Collins, Harry (1985): **Changing Order, Replication and Induction in Scientific Practice**, 1992 edition, The University of Chicago Press
Collins, Harry (1992): **Afterword, Science Acts** in [1992 edition of Collins (1985)]
Fujimora, Joan (1992): **Crafting Science: Standardized Packages, Boundary Objects, and "Translation"**, in [Pickering 1992] pp. 168-211
Gibbons, Limoges, Nowotny, Schwartzman, Scott & Trow (1994): **The new production of knowledge. The dynamics of science and research in contemporary societies**, London: Sage
Haraway, Donna J. (1991): **Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective**, in Haraway, D: 'Simians, Cyborgs and Women', New York: Routledge
Hvenekilde (1993): **Interfacing Room Simulation Programs and Auralization Systems** in *Applied Acoustics* vol. 38 pp. 333-347, England: Elsevier Science
Knorr-Cetina, Karen (1998): Epistemic Cultures
Latour, Bruno (1993a): **We Have Never Been Modern**, Harvester Wheatsheaf
Lave, Jean & Etienne Wenger (1991): **Situated Learning. Legitimate Peripheral Participation**, Cambridge, University Press
Law, John (1987): **Technology and Heterogeneous Engineering: The Case of Portuguese Expansion** in [Bijker, Hughes & Pinch 1987] pp. 111-134
Nilsson (1993): **Acoustium -Another Hybrid Room Acoustical Model** in *Applied Acoustics* vol. 38 pp. 131-143, England: Elsevier Science
Polanyi, Michael (1966): **The Tacit Dimension**, New York: Anchor Books, Doubleday & Campany
Star, Susan Leigh & James R. Griesemer (1989): **Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39**, *Social Studies of Science*, Vol 19, (1989), pp. 387-420
Suchman, Lucy A. (1987): **Plans and situated actions: the problem of human-machine communication**, Cambridge University Press, ch. 3-4 (p.27-67)
Van Lente, Harro (1993): **Promising Technology. The Dynamics of Expectations in Technological Developments**, thesis, Enschede: University of Twente