

Strategic niche management as an operational tool for sustainable innovation : guidelines for practice

Citation for published version (APA):

Caniëls, M. C. J., & Romijn, H. A. (2006). *Strategic niche management as an operational tool for sustainable innovation : guidelines for practice*. (ECIS working paper series; Vol. 200607). Technische Universiteit Eindhoven.

Document status and date:

Published: 01/01/2006

Document Version:

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

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Eindhoven Centre for Innovation Studies

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Operational Tool for Sustainable Innovation:
Guidelines for Practice**

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Working Paper 06.07

Department of Technology Management

Technische Universiteit Eindhoven, The Netherlands

March 2006

**Strategic Niche Management as an
Operational Tool for Sustainable Innovation:
Guidelines for Practice**

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Paper for the Schumpeter Conference 2006, 21 -24 June, Nice, France

Abstract

Strategic Niche Management provides an evolutionary analytical framework that has proven useful for the analysis of success and failure in the introduction of radical innovations in fields such as wind energy, biomass, public transport systems and food production. However, SNM has yielded few detailed and practical "how to do it" guidelines for practitioners interested in how to incubate new technologies. This paper takes one step towards greater operationalisation of SNM as a practical tool for managing the development of radically new technologies. We consolidate the existing SNM studies to identify the main gaps in that literature. Then we bring in studies on the development and commercialisation of radical innovations in large companies and draw lessons from these with respect to "how to do" radical innovation, shedding new light on the nature of niche-based learning processes that are needed for these innovations to mature. A number of concrete guidelines for implementing the Strategic Niche Development approach are given.

Keywords:

Strategic Niche Management, radical innovation, sustainability, innovation management, evolutionary theory

1. Introduction

This paper is concerned with the introduction of sustainable radical innovations. Experience shows that this is usually a complex and protracted process with a high likelihood of failure. Strategic Niche Management furnishes a evolutionary framework that can help to understand this process better, by allowing insight into the reasons why new technologies may fail to catch on, even though they promise superior performance compared to incumbent technologies. This phenomenon of inertia is seen to derive from the fact that technologies are embedded in a broad and complex system, a 'technological regime', which consists of manifold interacting technological and societal elements. Mature incumbent technologies and the existing technological regime are well attuned to each other as a result of a long process of incremental co-evolution. Whereas regimes can cope well with incremental technological improvement, they are less well suited to coping with the emergence of new technologies of a more radical nature, since their successful introduction and diffusion require simultaneous adaptations in all major system parameters (Kemp *et al.*, 2001; Elzen *et al.*, 2004; Weber *et al.*, 1999). In order to address the problem, the SNM approach advocates the creation of niches -- protected spaces in which new technologies are given opportunities to incubate and mature through gradual experimentation and learning by actor networks of producers, researchers, users, governmental and other organisations. Niche creation is undertaken in steps (see, for example, Kemp *et al.*, 1998).

The SNM framework has proven useful for *ex-post* analysis of success and failure factors in the introduction of specific radical innovations, such as wind energy, biomass, public transport systems and food production. However, despite some claims to this effect, to date the SNM literature has yielded few detailed and practical "how to do it" guidelines for practitioners interested in niche creation. It is especially hard to find specific clues for action to ensure effective learning by the concerned stakeholder network in the desired direction, and how successful learning experiments can be set up and managed. Partly, this is caused by the fact that SNM is an approach that has been developed only recently, and to our knowledge the insights yielded by individual experiences have not been compared and integrated with a view to deriving systematic guidelines for future action. Potentially important patterns contained in the SNM studies may therefore remain hidden from view.

To illustrate the problem from the workbook by Weber *et al.*, one of their key suggestions about how to set up an experiment is that "At all stages within a project, choose a management style which maximises operational effectiveness" (1999, p.74). However, this is a tautological statement. Which project would deliberately select a management style that is expected to lead to sub-optimal results? What we need to know, rather, is which concrete management principles can best be applied in SNM experiments. But the SNM literature remains vague on this score. One is told to "Keep the experiment sufficiently broad in terms of partners (users, suppliers, government, operators) and have committed partners in the team" (p. 39). But how does one go about involving stakeholders who are evidently of key importance to the experiment, but who do not show any interest in joining the network? And how does one keep one's partners motivated when the experiment does not yield quick results, and there is no money for adequate compensation of their efforts? How does one treat important stakeholders who wish to leave the process midway? These tend to be the sort of questions that practitioners managing SNM experiments are likely to come up against.

A second cause of lack of practical application, in our view, is that SNM has its roots in evolutionary theorising. The main strength of this field is that it allows a coherent conceptual perspective on how technological innovation processes unfold, as a result of interacting stakeholders operating in innovation networks within a broad societal context. However, SNM has no clear link with business management studies, which concentrate on the practical management of innovation processes by people within particular organisations. That micro-micro level of innovation management remains something like a black box in SNM. We feel that SNM could benefit a great deal from the lessons that have already been drawn from company experiences with radical innovation in the strategic management literature. The analysis in these studies is not couched in terms of regimes, niches, and path dependency, but there cannot be any doubt that the experiences involved in new product development processes do in many respects resemble the incubation and learning processes documented by the SNM writers.

The aim of the paper is to take one step towards greater operationalisation of SNM as an ex-ante policy tool. First, we consolidate the existing SNM studies to identify in systematic fashion, factors

that appear to be commonly associated with success (or failure). Second, we bring in studies on the development and commercialisation of radical innovations in large companies and draw lessons from these. This literature, consisting of both conceptual work as well as empirical case studies, does yield a lot of detailed hands-on insights into "how to do" radical innovation. Thereby, it sheds light on the nature of niche-based learning processes that are needed for these innovations to mature. By pooling the lessons from these two reviews, we are able to identify several common organisational and institutional factors associated with innovation success. On this basis we suggest concrete guidelines for implementing the Strategic Niche Development approach in practice.

We start with a summary of the SNM approach, and its limitations as an ex-ante innovation management tool, in section 2. Then follows a systematic review of factors promoting radical innovation success as reported in the SNM literature itself, in section 3. In this way we identify three specific aspects of the SNM process that have not been covered properly in the extant SNM studies. In section 4 we apply insights from radical innovation studies to these aspects. Final conclusion and recommendations are contained in section 5.

2. SNM and its limitation as a policy tool

According to SNM authors, the difficulties associated with successful introduction and widespread uptake of radically new technologies emanate from a variety of factors. A useful overview of these is provided by Kemp et al (1998, pp. 177-180), which we follow here.

Firstly, underutilisation of new technologies may be due to technological factors. In some cases, the use of a radically new innovation may require complementary technologies that may not be readily available, or that are expensive. On the side of customer firms, for example, proper utilisation of a new piece of equipment may also require adaptations in the rest of their production process. A similar phenomenon operates on the side of the potential producers of the innovation. Given the uncertain market prospects surrounding many new technologies, it is far from certain that producers will face sufficient incentives to invest in making the changes in their production processes that would be required to start producing the innovative product. Other technology-related barriers to adoption of radically new technologies could emanate from the fact that the new technology itself has not yet been fully tried and tested, and is therefore still likely to suffer from teething problems. High unit cost of the innovation due to low initial scale of production and lack of dynamic learning economies may also deter potentially interested customers.

Cultural and psychological factors could be another stumbling block to the full utilisation of new technologies. Due to lack of knowledge about the characteristics of new technologies, potential users may be deterred because they may be sceptical about their performance in comparison to the technologies that they currently use. Somewhat related to this, there could also be economic barriers on the demand side associated with prospective users' preferences, risk aversion and willingness to pay for new unknown items.

A further factor holding back radically new technology development is related to governmental policy and the regulatory regime. Even in the face of evident societal and environmental pressures favouring more sustainable technologies, governments may not have the political will to introduce the required enforcement measures, develop clear policy guidelines and strategies, implement a consistent incentive framework, and adhere to these policies over a sufficiently long period of time. Often, the policy regime continues to favour incumbent, less sustainable technologies.

Infrastructure and maintenance factors could also hold back the quick adoption and diffusion of new technologies. Distribution and communication networks and knowledge and skills may need to be adapted to new requirements. This tends to be a costly affair, given the large sunk costs in these sectors. Efforts to adapt or upgrade these supporting areas will only begin to be forthcoming when it has become clear that the new technology is likely to have a substantial impact on the market.

Finally, possible undesirable societal and environmental impacts associated with the introduction of the new technology may hold back their widespread acceptance. Experience shows that new technologies that are designed to solve certain problems may simultaneously have new unfavourable effects, such as unanticipated waste problems that take time to sort out.

Kemp *et al.* (1998) conclude that the combined effect of all these factors, which may also reinforce one another, tends to induce technological inertia. Along with other SNM authors, they

propose to overcome this by creating "temporary protected spaces for more sustainable technologies. These spaces, in the form of technological niches, could function as local breeding spaces for new technologies, in which they get a chance to develop and grow. Once the technology is sufficiently developed in terms of user needs, and broader use is achieved through learning processes and adaptations in the selection environment, initial protection may be withdrawn in a controlled way." (Kemp *et al.*, 1998, p. 185).

How, then, are these protected local breeding spaces to be created? SNM authors distinguish three principal policy strategies (See, e.g., Raven, 2005, p. 55). The first one is the "classical steering paradigm", which relies on central planning, command and control. This entails setting specific goals and employs policy instruments like formal regulations, rules and laws that are implemented from above. Contrasting with this strategy is the "bottom-up market model", in which policy makers seek to influence the behaviour of local actors through intervention in market prices, using instruments such as generic financial incentives and tax exemptions. The third alternative revolves around networking. The main thrust of this policy strategy is the nurturing of networks between various actors that have a role to play in the innovation process. The idea is that the incubation of new innovations will be facilitated when variegated individuals, groups and organisations that have a stake in that innovation will have opportunity to collaborate and exchange information, knowledge and experience, thus embarking on a collective learning process. Relevant policy instruments are the organisation of seminars, workshops and experiments.

SNM authors set great store by this third policy option, particularly for the purpose of sustainable regional development. In this connection Raven observes that the strategy can help create different learning and experimentation hubs in a region, which can in turn cross-fertilise each other through organised forums for knowledge sharing, exchange and comparison, a process which he calls *cosmopolitisation*: "Policy actors involved can play a crucial role in cosmopolitising experiences, by formulating a regional vision (supported by the stakeholders), through network management (bringing actors together), by enabling learning (monitoring results from different experiments) and by exchanging lessons (organising seminars and meetings and publishing results)" (Raven, 2005, p. 274). Furthermore, such a strategy can maximise opportunities successful learning through intelligent selection of areas for experimentation. By concentrating on the promotion of experiments in fields where the dominant socio-technological regime is ready for change, they maximise opportunities for successful learning and innovation trajectories. (Raven, 2005, p. 274).

Kemp *et al.* (1998, p. 186) distinguish five steps in the process of niche creation: (1) choice of a promising candidate technology; (2) choice of an appropriate setting for the learning experiment, i.e., an area where the advantages of the technology count highly, and its disadvantages count less; (3) set-up of the experiment, which includes the need to find a good balance between protection and performance pressure; (4) scaling up the experiment by means of public support measures; (5) dismantling of protection, in order to avoid permanent support-dependence and promote increasing competitiveness.

Although bit and pieces of the policy process within each of these five steps have been discussed in various SNM publications (Weber *et al.*, 1999; Kemp *et al.*, 2001; Kemp *et al.*, 1998; Elzen *et al.*, 2004) to the best of our knowledge there does not exist a comprehensive overview from where aspiring SNM policy practitioners could learn the tricks of the trade in detail. The SNM writers themselves also acknowledge the lack of guidelines for concrete action within the five steps. In the most practical SNM publication, a workbook compiled by Weber *et al.* (1999), it is observed that "Until now ... Strategic Niche Management ... has been developed as a tool for analysing *past* experiences. ... Can SNM be a 'tool' to support *decision-making, planning and forward-looking* analysis? For the moment, these constructive applications have been explored to a very limited extent." (1999, p. 86, emphasis added). In another study, Brown *et al.* (2004), we read that "... with a few exceptions, little systematic study has been done on defining and monitoring the learning processes [in an experiment]" (Brown *et al.*, 2004, p. 195). Furthermore, Raven identifies the use of SNM as a practical policy tool (as opposed to a research instrument) as being an important issue that deserves more attention: "SNM can be used for improving the design of experiments, for evaluating policies in the past, or for using SNM as part of scenario development, or for designing future policies on niche management. However, SNM has not been used as such in practice, but mainly as a research

tool. The policy claims that are often made by SNM researchers still remain a promise; SNM needs real-life experimentation in society." (Raven, 2005, p.272).

The nearest to a set of policy guidelines for transition management can be found in a report for the Fourth National Environment Policy Plan written for the Dutch government (Geels and Kemp, 2000). In general, policy makers should exert pressure on the existing regime, while simultaneously stimulating alternative technologies. The authors suggest that generic instruments such as tradable emission rights, emission norms, and competition policy are most likely to be effective to achieve the first aim, whereas they envisage more specific stimulation measures to nurture new technologies. Policies should further aim to bring about synergies across niches; try to stimulate hybrid technologies that can act as bridges in a transition from the incumbent to a new regime; take advantage of opportunities for niche development afforded by the emergence of new markets with new requirements; and stimulate different technologies with complementary characteristics. To achieve this, the government must adopt a plural role: it should act as initiator of societal debate, stimulate experiments, ensure that learning takes place on the basis of these experiments, and safeguard the continuity of the process (pp. 53-55). However, the authors of the report admit that their discussion about the role of government is still tentative and should be subject to further research, especially in respect of suitable instruments and tools (p. 58).

In the following two sections we will address the two causes that in our view lie at the basis of the lack of practical operationalisation of the SNM technique. In the next section (3), we consolidate of the SNM literature for the purpose of systematically drawing out detailed policy lessons. After exhausting the SNM literature, we will extend our focus to the literature on radical company innovations in section 4.

3. Review of the SNM literature

The purpose of the review in this section is to identify common factors of radical innovation success and failure from the major SNM studies that have been undertaken so far. We perused the studies with the following questions in mind:

1. What are the main characteristics of the niche creation process, according to the SNM authors?
2. Which contextual factors in the regime and the landscape influence that process?
3. And how can one manage the niche creation process successfully? This includes not merely drawing lessons from successful experiences, but also learning from what went wrong in less successful cases.

We are ultimately interested in answering the third question, while the answers to questions 1 and 2 are instrumental to achieving that aim. We included both conceptual studies whose authors expound on how these things ought to work according to predictions derived from evolutionary theory, as well as empirical work whose authors have drawn ex-post lessons from practical experiments.

3.1 The main characteristics of the niche creation process

The various SNM authors have a shared view on the nature of the *niche formation process*. It is seen to consist of three sub-processes that are interrelated and mutually reinforcing (Raven, 2005, p. 43). Firstly, niche formation is meant to match the promises held out by the innovation and the stakeholders' expectations about it, with the needs in society that the innovation is meant to satisfy (Kemp, 1998, p. 190). Secondly, niche formation revolves around experimentation-based learning about the technological and environmental possibilities and constraints of the innovation, about the discovery of specific application domains and its uses in these domains, about its acceptability (or lack thereof) by social groups and individuals, about suitable policies to regulate or promote it, and so on. At the same time, social actors themselves change their views and align their expectations about the new technology over time, under the influence of further development of the new technology, and their exposure to it. The potential benefits and the limitations of the new technology for people become clearer as the experiment evolves. People's expectations about it become more specific and consistent ("robust") as initial vague beliefs give way to accumulating facts, figures and experiences (Hoogma, 2000, p. 86; also cited in Raven, 2005, p. 39). To sum up, Kemp et al. (1998) say that "experiments are a way to stimulate articulation processes that are necessary for the new technology to

become socially embedded" (p. 190). Or, in the words of Weber *et al.*, through experiments one seeks "broad coverage of opportunities for learning about new implications of a technology" (1999, p. 49). Thirdly, niche creation is widely seen to require the development of a co-operating actor network. According to Hoogma, it will be conducive to success when actors' motivation to participate are not centred on short-term financial gains (2000, p. 84). Furthermore, the composition of the network is important, and this may need to change or expand over time in order to facilitate niche growth. The role and activities of incumbent partners may also change over time (Kemp *et al.*, 1998, p. 191). Following Von Hippel (1986), who emphasised the usefulness of intensive user-producer interaction for successful innovation, SNM authors advocate that users have a particularly important role to play in SNM networks. Domination of industry is seen to be undesirable (Hoogma, 2000, p. 85), and users have a more active role to play than as mere sources of market information (Weber *et al.*, 1999, p. 68; Hoogma and Schot, 1999). Finally, the participating actors in the network should share a common core view about where they are going with each other and with the technology. Actors' strategies, expectations, beliefs, practices, visions, and so on, must go in the same direction, run parallel (Hoogma, 2000, p.85). Sometimes, therefore, an already existing social network that evolved for some unrelated purpose can serve as a useful basis for designing a new experiment. However, this may not always work well, especially when it means that stakeholders that are important to the development of the new technology are left out (Raven, 2005, 40-1, citing Hoogma, 2000, p. 353).

3.2 Contextual factors

When going through the SNM studies, we noted a number of factors that could qualify to be listed under the heading of context. We chose to structure them under two main headings: (1) preconditions that require to be fulfilled in order for SNM-type experimentation to be possible at all; and (2) facilitating conditions that stimulate or enhance niche processes, but that are not strictly required for those processes to be able to operate. Within this second category, there are two sub-groups, namely: (2a) facilitating conditions that cannot be manipulated in the short term, but can change over longer periods, and in this way shape a more conducive climate for experimentation and learning with new technologies; and (2b) facilitating conditions that are amenable to (short-term) change through policy intervention. Our classification is thus different from the classification of contextual factors in terms of regime and landscape commonly utilised by SNM writers. We chose a different approach because there are manifold factors in both the regime and the landscape that affect niche development. We wanted to isolate (if possible) the factors that are absolutely necessary for niche formation to occur, from the (many) other factors that are merely facilitating that process but whose absence will not necessarily imply the death of niche formation. Furthermore, users of the SNM technique in practice have commented on the difficulty of allocating certain influencing factors uniquely to either the regime or landscape.

Among the necessary preconditions (factors type 1) for SNM experimentation, *the availability of sheltered spaces for incubation* features prominently. As Kemp *et al.* observe, "A(n) ... important factor is the availability of niches or domains for application" (1998, p. 183). In other words, there should be an initial setting within which the new technology can be used experimentally, without immediate pressure for adequate technical and market performance. According to Kemp *et al.* (1998), this setting should be one in which the benefits of the new technology are valued highly. This could happen, for example, when incumbent technologies are suffering from particular problems that are considered to be serious by a group of people, who would therefore place a high value on a new technology that promises to remedy those problems and be willing to put up with initial high costs or teething problems. (p. 187). Various policies listed below may, of course, contribute to the availability of sheltered spaces, but the point is that these spaces *must* have been created before experimentation with a new technology can start.

Possibility for continuous evaluation & incremental improvement is another important precondition. The new technology must be amenable to incremental development in order for the experimenting stakeholders to be able to assess the results of their efforts regularly. Such regular assessment of what went wrong and what went right in experiments is the key to continuous learning. Not all new technologies satisfy these requirements well. For instance, some new technologies can

only be used or applied after they have already reached a relatively advanced stage in their technological development trajectory, and therefore do not lend themselves to an SNM strategy.

Yet another requirement is that the *new technology must exhibit possibilities for capturing temporal increasing returns or learning economies* (Kemp *et al.*, 1998, p. 187). Kemp *et al.* (2001) say that the extent to which a technology is conducive to appropriate learning should be an important criterion in the choice of experiment (p. 291). This argument goes back to the debate about protection of infant industries in the industrialisation process. Economies can be of the static or dynamic type, or a combination of both. The basic idea behind static economies is that it takes time to build up a critical minimum market size beyond which economies of scale begin to occur in a new production process. Dynamic economies occur when accumulated experience with a new technology over time leads to "learning-by-doing".¹

Still another important precondition to successful experimentation is that the *new technology should still be open to development in different directions* (Kemp *et al.*, 1998), in order for evolutionary variation and selection processes to be able to work. This means that the technology should still be at the stage of an initial workable prototype that holds a plausible promise of benefit to the stakeholders, but still has sufficient scope for branching and extension. But the satisfaction of this technological prerequisite by itself is not sufficient for variation and selection to occur. Kemp *et al.* (1998) note that the attitudes of the participating actors also matters. They must be open to investigating the technology's potential in different directions.

A final prerequisite is that the technology should be "...*already attractive to use for certain applications in which the disadvantages of the new technology count less and the advantages are highly valued*" (Kemp *et al.*, 1998, p. 187, italics added; see also Kemp *et al.*, 2001, p. 290). This point is illustrated well in a novel traffic regulation scheme, whose successful development in Durham (UK) was aided by a combination of local pull and push factors in its favour: "The proposed Durham scheme held out the promise, to the local stakeholders, of solving a major traffic problem, which was considered all the more important because its Cathedral and Castle are World Heritage Sites. In addition, acceptance was aided by the knowledge that this proposal was the only possible alternative still left untried except for a total traffic ban, which was considered undesirable" (Ieromonachou *et al.* 2004, p. 83).

In sum, most of the prerequisites for niche experimentation that we found in the SNM studies have to do with certain technological characteristics of new technologies. Mainly, they should still at a 'workable prototype' stage, and be amenable to possibilities for incremental development through variation and selection. This can only happen when improvements can be assessed on a regular basis. But even when all these technological requirements are met, successful niche experimentation will only occur when some societal preconditions are also met. These are in the sphere of values and attitudes that must be conducive to experimentation on the new technology, initial attractiveness of the technology for certain applications, and the availability of sheltered spaces for further incubation. To the extent that we can judge on the basis of the still limited number of SNM studies, this combination of factors thus constitutes the basic prerequisites for niche creation processes to work. If one of these prerequisites is not satisfied, the process cannot work.

Aside from the necessary conditions just outlined, the SNM studies yielded several external conditions that stimulate (or hamper) experimentation (factors type 2), but are not strictly necessary for the niche creation process to work. We first look at the conditions that are more or less given in the short term (type 2a).

Problems experienced in the dominant regime that cannot be solved within the parameters set by that regime will lead to *structural regime instability*, and in this way facilitate the emergence of alternative technologies (Kemp *et al.*, 1998, p. 184). According to Raven (2005), there are three ways in which regime instability can achieve this: "First, regime instability can create local opportunities for experiments, because niche actors develop expectations and visions linked to regime instability ... Second, when stability in the regime decreases, regime actors may become interested in the niche ... they expect the niche to be a promising option for the future. ... Third, in cases of very high instability, regime actors may adopt the niche as a problem solver" (p. 260). This point is illustrated by the case of a new type of bread (Zeeuwse Vlegel) made from a traditional grain variety that was

¹ A classic article on the subject is Baldwin (1969).

reintroduced in a region in the Netherlands: "Agricultural and food safety crises as well as the institutionalisation of food quality debates within the dominant regime [...] created room for the emergence of new approaches to food production and marketing" (Wiskerke, 2003, pp. 445-6). Potential for successful niche development is particularly high when regime instability leads to a high shared need for, and urgency of an innovation, such as severe traffic congestion or environmental degradation. Kemp *et al.* (1998) go so far as to say that "the new technology must greatly alleviate a social problem" (p. 187), while Brown *et al.* (2004) state that "a shared sense of urgency is required for successful learning" (pp. 215-6).

However, regime instability by itself will not initiate niche development. As Kemp *et al.* (2001) point out, *sufficient institutional support, actor skills, knowledge and techniques* must also be available in the existing regime to enable a regime shift (p. 276). In addition, there must be a *broad public support base* for experimentation. For example, "partners in the Durham scheme had a commercial or clear interest in the case succeeding" (Ieromonachou *et al.* 2004, p. 85). Building a broad support base can be problematic when initiators who are interested in forming networks for niche development are too activist, or have values that are too far removed from commonly held views in society, so that it is difficult for them to compromise with less radical stakeholders. Thus, according to Brown *et al.* (2004), "... activist visionaries frequently initiate such technological experiments that they must build heterogeneous coalitions ... Incongruent visions and interests, low commitments and levels of risk taking by key actors are likely to emerge in such experiments. In contrast, in BSTEs [Bounded Socio-Technical Experiments] where an existing local problem is collectively recognised and where an innovative technology is one of several approaches to solving the problem, ... [these problems] are less pronounced" (p. 216).

Finally, we also found facilitating conditions for niche formation that are in the sphere of appropriate interventions (factors type 2b). Kemp *et al.* (1998) refer to these conditions when they note that regime shift does not merely entail the promotion of a new technology, but the management of the whole transition process. Several policy instruments can be utilised for the purpose. *Incentive policies* such as tax and reward systems can make emerging technologies (temporarily) more attractive by changing relative prices of different options (Kemp *et al.*, 1998, p. 184; Kemp *et al.*, 2001, p. 279). *Centralised planning activities* also have a role to play. Governments' role is to plan for the creation and building of a new socio-technical regime (Kemp *et al.*, 1998, p. 185; Kemp *et al.*, 2001, p. 279). These types of policy, decentralised (market incentive-based) and centralised (planning-based) need to support one another; they are likely to be ineffective when applied on their own. And in addition, *direct network formation activities* must also be part of the policy mix. "A purely top-down centralised policy is likely to fail, because it is insensitive to the actual practices, problems and preferences in local networks built around the innovative technology. A purely bottom-up approach, on the other hand, focused on generic instruments through investment grants, tax exemptions, and favourable tariffs reflects a naive perception and strong belief in the self-organisation of local actors ... market instruments should not be too generic, but niche-specific, and be accompanied by a process and network management strategy to create a social network that is eventually able to continue niche development without external financial resources" (Raven, 2005, pp. 267-8).

An essential aspect of the management of regime shift is also the *identification of promising next steps* when the niche process is underway. A useful way to do this is to conduct visioning exercises among stakeholders, and to review the progress in ongoing technological experiments periodically in the light of the long term views developed through visioning. Visioning is important for developing some notion of a long-term desired direction, which then forms a yardstick by which the outcomes of the intermediate phases in the experimentation process can be evaluated and promising next steps identified (Elzen *et al.*, 2004, 290).

3.3 "How to do" guidelines for niche formation

In the following discussion about the actual conduct of the niche creation process, we follow the five-step division adopted by SNM authors (see, e.g., Weber *et al.* 1999; Kemp *et al.*, 1998; and Kemp *et al.*, 2001), namely: (1) the choice of technology; (2) selection of the experiment; (3) the set up / implementation of the experiment; (4) the scaling up of the experiment; and (5) breakdown of protection by means of policy. Some of the niche management guidelines that we found in the SNM

literature are, however, applicable to more than one stage in the process. We have chosen to discuss each guideline under the step where it first occurs, and if necessary we refer back to it in the discussion of the subsequent steps.

Step 1: The choice of technology

Weber *et al.* (1999) say that the technology to be selected for experimentation must be chosen 'smartly' (p. 61). But what does that mean, concretely? First of all, the experiment should adhere to the principle of Keep It Simple, Stupid (KISS). It is easy to underestimate the complexity of niche processes. It is therefore wise to start simple and add complexity in later stages, when the basic features of the new technology and the associated organisational aspects have been mastered. The stakeholders involved in the development of the Durham traffic scheme had understood this principle well: "The small size and scope of the scheme made it technologically simple to introduce with relatively few people directly affected" (Ieromonachou *et al.*, 2004, p. 83).

A second crucial aspect in the selection of a new technology, observed in all the major SNM studies, is the presence of a change agent who champions the innovation. Kemp *et al.* (1998, p. 183) see these change agents as entrepreneurs who build new technological systems. In the words of Kemp *et al.* (2001): "...new systems are created by system builders - people of imagination and persistence who perceived early on the opportunities offered by a new technology, who conceived the new technology as the constitutive part of a new system, and who managed the transition process towards a new system. History of technology is often written round these entrepreneurs, picturing them as people of vision and determination ... All of them had a vision of what the new system should look like, and were determined solvers of the many problems frustrating the growth of the system" (pp. 273-4). Judging by the road transport scheme in Durham, the need for such change agents would seem to hold true for policy innovations just as well: "Elected representatives and the officials of Durham County Council ... championed the scheme for many years" (Ieromonachou *et al.* 2004, p. 83).

From Brown *et al.* (2004) we learn what personal characteristics these entrepreneurs should have. They need to be outwardly oriented, open, adventurous, tolerant of uncertainty, flexible and able to facilitate others rather than to control them, in order to create an environment conducive to trial and error. They must also be able to reflect on, and evaluate their own contribution to the process in a constructive manner in order to be able to adapt in response to changes along the way. In other words, they need to have a capacity for learning. (p. 196). Roep *et al.* (2003) see change agents as visionaries, who "... are needed to make the connection between societal developments at landscape level, putting pressure on the dominant regime, and the room for manoeuvre at the local level. Their capacity is to envision windows of opportunity, express expectations and enrol alliances" (p. 212). The farmers' co-operatives (VEL and VANLA) studied by them showed that local leaders played an important visionary role. According to Brown *et al.* (2004), it is even necessary to conduct explicit visioning exercises, in the start up phase as well as in subsequent stages of the project (p. 215).

A third important criterion for choosing a new technology is that it must be broad enough so that different technological options are still open in the beginning (Weber *et al.*, 1999, p. 37). Yet, at the same time the concept should be sufficiently specific to offer a plausible promise of benefit to stakeholders: "The concept identified as promising should be sufficiently specific to inspire other stakeholders that innovation should be attractive enough and the objective should be reachable within a reasonable time frame, and sufficiently open to be modified during the further experimental process" (Weber *et al.* 1999, p. 33). And a fourth technology-choice criterion refers to the actual or feasible organisational features associated with the new technology, which must be compatible with user needs and values. Weber *et al.* (1999) say that the chosen technology must have organisational characteristics or requirements that are close to the existing regime, but with promises of substantial changes in the long term (p. 35).

Step 2: The selection of an experiment

The KISS principle and the presence of an innovation champion are not merely seen to be important for the choice of technology, but also for the selection of an experiment. In addition, this phase in the niche creation process entails some new principles that have to do with creating conditions that will induce the learning process. First of all, it is important to aim high, but not too high. The experiment must be chosen in such a way that the goal constitutes a challenge for the actors concerned, but at the

same time the objectives must be achievable within a reasonable time frame, otherwise there is a risk of the experiment petering out (Weber *et al.*, 1999, p. 35). Ideally one should keep a balance between a high reward strategy that entail high risk, and a more conservative incremental low-risk strategy. (*Ibid.*, p. 65).

Secondly, it is important to initiate user-producer communication already at this early stage. Critical input from users who are able to communicate their requirements push suppliers to constantly improve the innovation (Kemp *et al.*, 2001). So-called lead users have a key role to play at this stage. Since they adopt innovations faster than the majority of other users, they can provide feedback at early stages in the innovation process (Von Hippel, 1986). Lead users should thus be engaged when the experimental partner network is being formed (Weber, *et al.* 1999, p.68). At the same time, care should be taken that these lead users are still reasonably representative of the large majority of subsequent potential adopters. If the pioneer users have too idiosyncratic or modern requirements, the technology may never reach the larger group (Kemp *et al.*, 2001, p. 291).

Step 3: The set up / implementation of the experiment

Different actors have a role to play at the stage when the experiment is set up, although the SNM literature is decidedly vague about who should be doing what. It is merely observed that "...The choice of niche policies needs to be based on the barriers to the use and diffusion of the new technology" and that "...Possible elements of such a policy are the formulation of long-term goals, the creation of an actor network, co-ordination of action and strategies and, where needed, the use of taxes, subsidies, public procurement and standards" (Kemp, *et al.*, 1998, p. 188). The innovation champion, already introduced above, is clearly needed here for the purpose of goal setting and constituting the actor network, and later on for the facilitation of the actual learning process. But this is also the stage when long-term policy strategy must be formulated, and incentive policies designed in line with that strategy. Unless the innovation champion is also a policy maker, these tasks would be executed by different people. The above-mentioned need for co-ordination of action and strategies presumably refers to the need for co-ordination between these different actors.

The focus of the above activities should be to induce - and maintain - learning in networks. Kemp *et al.* (2001, p. 291) even go so far as to say that achieving the initial goal is less important than the achievement of high-quality learning experiences and successful actor network building. The learning ideally comprises a whole range of aspects, including the discovery of problems and how they may be solved; the adjustment of the technology to fit into the existing socio-technical system; the identification of different types of potentially interested customers; the various uses of the technology; and suitable commercialisation strategies (p. 293). An exploration of the types of market pressures that could be operational in the experiment should also be part of the learning process (Weber *et al.*, 1999, p. 41). The learning thus includes both technological and social, managerial and organisational network features, as well as the complex interactions between the technological and the societal aspects (Wiskerke, 2003, p. 446; Roep *et al.*, 2003; Truffer *et al.*, 2002).

Ideally, the validity of the lessons goes beyond the specific experiment at hand. In this connection, mention is made of the importance of double loop learning (Hoogma, 2000; Roep *et al.*, 2003; Truffer *et al.*, 2002): "... The evaluation of experiments should be done with reference to the larger overall picture of technology development and sustainable development. A good experimental setting will -- even in the case of failure -- be able to generate results that are of relevance to a broad range of development paths" (Truffer *et al.*, 2002, p. 115).

We now turn to the managerial principles whose application in the conduct of the experiment is seen to be associated with effective ongoing learning by the network actors. Amalgamating the insights from the different SNM sources has clear value added, because although each SNM study offers some insight on this subject, the knowledge on this aspect is highly fragmented.

A sound principle is to *build on what is already there*. One must seek out and utilise existing strengths in terms of actors' knowledge, skills, experiences, network relations, assets, and so on (Weber *et al.*, 1999, p. 71). Then, the overall management strategy should be one of "going with the flow", utilising the ongoing dynamics of socio-technical change while exerting pressures to nudge the learning process in desired directions (Kemp *et al.*, 1998, p. 185; Kemp *et al.*, 2001, p. 280). This constitutes a cyclical process. Due to limited foresight, one can only proceed in small steps, followed by evaluation and adjustment of goals and strategies, if needed (Elzen *et al.*, 2004, p. 288). Truffer et

al. (2002) call this *reflexive experimentation* (p. 114). In the course of this process, strategies and actor expectations are adjusted to each other. This continues even after the experimental phase is over (Wiskerke, 2003, p. 446). Niche development has a higher change of success when this process is used to *explore several technological trajectories or promising options in parallel* (Raven, 2005, p.253; Roep *et al.*, p. 211; Truffer *et al.*, 2002, p. 114). Raven advances several reasons why this would be so. A larger market size may result when a new technology is tried out in different geographical markets or application domains simultaneously. Concurrent experimentation also enables faster learning because different actor groups can learn from each other. And multiple options entail more chances of success (p. 253). Furthermore, these processes can be helped along by *long-term scenario-building* exercises that encourage actors to "think out of the box". Methods include visioning, system thinking, and mental model building, among others (Brown *et al.*, 2004, p. 200; Truffer *et al.*, 2002, p. 122).

Several practical rules of thumb can aid successful learning. First and foremost, it is important to apply the aforementioned *KISS principle* again at this stage of the niche creation process. It is all too easy to underestimate the complexity of a new technology, both in a pure technological sense as well as in terms of the societal implications that its adoption would entail. It is therefore a sound idea to start off with a simple, but robust prototype, and add on more complex features gradually, when the core principles have been mastered. The earlier-mentioned principle of *aim high, but not too high*, is closely related to this, but this principle relates to the management of the stakeholders in the experiment rather than to the technology itself. A good way to ensure that partners remain motivated and engaged is to start off with modest but sufficiently challenging intermediate goals, and to raise the stakes only when these have been achieved. Furthermore, an *attitude of openness and flexibility* on the part of all actors in the experiment is essential. There should be a willingness to change course in midstream when it has become obvious that a dead end has been reached (Brown *et al.*, 2004, p. 196). That means that stakeholders - and in particular the innovation champion - should avoid developing too much attachment to 'their baby'.

Actors must also strike "... a [continuous] balance ... between protection and selection pressure" (Weber *et al.*, p. 40, pp. 56-57, italics added). On the one hand, they must ensure sufficient protection, so as to avoid the experiment coming to a premature end due to competition from incumbent technologies. This protection could consist of government policy measures such as subsidies or tax relief, but also of ensuring R&D funding commitments by private actors participating in the experiment. At the same time, coddling should be avoided. It creates unrealistic expectations, induces inertia, and allows unproductive experiments to keep running (p. 77). A concise way of putting this is that the incentive structure must consist of a judicious combination of carrots and sticks to keep the learning on track. The importance of this principle is illustrated well by the case of the Durham road scheme, which consisted of a mix of measures that would make the scheme more acceptable (such as a complementary bus service) and measures to enforce it (Jeromonachou *et al.*, 2004, p. 86). Also, unexpected events like failures, surprises, public media attention and various adverse incidents (or threats of such events) are to be utilised as inputs for learning. One can *learn from failed experiments as well as from successful ones* (Weber *et al.*, 1999, p. 40; Brown *et al.*, 2004, pp 199-200). Actors must be encouraged to come forward to discuss the problems they experience. The often experienced tendency of sweeping project failures under the rug must be avoided. Moreover, experiments should be used to *challenge every assumption about the new technology*, including technology options, technology diffusion strategies, and effects upon patterns of use (Weber *et al.*, 1999, p. 73). It is helpful to *seek out independent external evaluators* to assess the progress in the experiment (Weber *et al.*, 1999, p. 76). They can cast the situation and the problems faced in a new light, thereby helping the actors to draw lessons from their work (Truffer *et al.*, 2002, p. 115).

Consultations with, and active involvement of project partners is essential for creating a broad support constituency behind the project. The local stakeholders need to achieve a sense of "ownership" over their project, so that they identify with it and feel responsible for its wellbeing. The people responsible for implementing the Durham road scheme has understood this well: "... the active involvement, and empowerment, of a number of project partners, once again over a number of years, combined with a widespread consultation process and publicity campaign ultimately helped the county council achieve consensus and support for changing" (Jeromonachou *et al.*, 2004, p. 83). A special effort should also be made *to create opportunities for interaction with the external actors who potentially will be affected*. They can bring fresh views to bear on the problem (Truffer *et al.*, 2002, p.

115; Weber *et al.*, 1999, p. 44), while interactions among actors around a shared goal or problem also enhances broad support for the project (Brown *et al.*, 2004, pp 199-200). The Durham scheme again illustrates the importance of this principle. It was not enough to work actively with those actually involved in the planning and management of the project. There were also affected groups who were not directly involved in the shaping of the project, but who did take part in consultations that helped form the various measures. Both types of stakeholders were represented in the design and evaluation of an experiment: "The consultation process both identified possible problems, and resulted in actors having a direct involvement in the design of the protection measures, such as the permits, bus provision and shop mobility service" (Ieromonachou *et al.*, 2004, p. 84).

Users have a special role to play among the stakeholders. In the Durham scheme, "... user involvement and understanding appears to have succeeded in minimising problems and maximising actor benefits, producing a win-win solution... Revision of the proposed measures was also undertaken in view of grounded opposition. This "... tailored the scheme to the needs of most groups' objectives without becoming less radical or less successful" Ieromonachou *et al.* (2004, pp. 85-86). Accordingly, users must be actively involved in the experiment on a regular basis. As Weber *et al.* (1999) note, user involvement does not come about spontaneously. Opportunities for voicing their concerns and ideas must be built into the design of the experiment from the start (pp. 42-43).

The management of the actor network assumes great importance in the SNM literature. First, it is necessary to ensure an *effective constellation of stakeholders* who connect effectively with one another. A triangular set up has been found to be particularly effective, composed of (i) innovating firms along with (ii) supporting actors such as researchers, technical advisers, consultants or extension officers, and unions, whose interactions are driven by (iii) endogenous development potential of the new technology as needed by the local constellation. This basic triangle is crucial because "... It makes local practices and resources into a starting point for further processes of unfolding (Roep *et al.*, 2003, pp. 211-212). *Monitoring potential barriers to effective co-operation* between the actors is crucial, especially when competing interests and potential free riding behaviour are at stake (Weber *et al.*, 1999, p. 78). It is therefore important to ensure a sufficient degree of reciprocity between the actors in terms of the distribution of the costs and benefits of the experiment (Roep *et al.*, 2003, p. 212). In particular, "... Care should be taken ... that the development of the technology is not dominated by industry, but that the users and 'third parties' can also contribute their ideas" (Kemp *et al.*, 1998 p. 191).

The *actor network must be managed dynamically*. As the experiment proceeds, the optimal network composition, required tasks and needed interactions will evolve (Weber *et al.*, 1999, p. 52) After the initial start up phase, niche expansion will often require the involvement of specific new actors. The existing actors in the network need to adjust their work and interactions accordingly (Kemp *et al.*, 1998, p. 191). These adjustment processes are not necessarily smooth if no explicit attention is paid to network stability. Maintaining individual responsibility for, and commitment to the collective goals, approach, and products, remains an important activity (Wiskerke, 2003, p. 446; Roep *et al.*, 2003, p. 212). Another important principle of good dynamic network management is that project partners should be free to join and leave. Partners who have lost their motivation along the way should not be persuaded to stay on, in order to prevent the atmosphere in the experiment from falling. As Weber *et al.* put it, "A clearly defined network of highly committed partners may be very effective in implementing an experiment, but it may be too inflexible and closed once changing boundary conditions of an experiment require the modification or the restructuring of the network" (1999, p. 38). It is thus better to be flexible, and not to have overly high expectations of one's project partners.

The *network for an experiment should be driven and guided by a network manager* (Weber *et al.*, 1999, p. 39), whose role is to co-ordinate the process, essentially ensuring that the network partners adhere to the principles already outlined above. It is mentioned that any actor, be it a public policy maker, a regulatory agency, a local authority, a private individual, a company, an NGO, an industry association, a citizen group, or a special interest group can play this role, depending on who is best suited for the particular task at hand (Kemp *et al.*, 1998, p.1988). However, we could not find much information about the question which specific management style the network manager could best adopt in order to be effective. All we could find was a statement that the tacit and vague expectations and visions of participants should be monitored, and that these should be articulated specifically" (Weber *et al.*, 1999, p. 47 and p. 70).

Instead, the SNM literature tends to elaborate on the role of public policy makers as a party who shape the context of experiments conducted by others. *Policy makers should assume the role of enabling actor and catalyst*, rather than regulator or technology sponsor (Kemp *et al.*, 1998, p. 191). Weber *et al.* urge policy makers to "Consider which kind of complementary policies could be conducive, needed or detrimental to the experiment" (1999, p. 53. and p. 75). An interesting observation is that financial contributions may not always be the most effective means of governmental support. The motivation to provide free inputs among stakeholders, and their willingness to improvise on a shoestring budget may be negatively affected when more plentiful resources become available. Weber *et al.* caution that 'funding to death' should be avoided (1999, p. 67). A more effective government intervention seems to be the creation of forward linkages, or 'demand pull'. In the case of the Durham road access improvement scheme, the local government first established favourable conditions for the innovation by means of a road charging policy in advance of improved public transport access to the area that was clearly linked to the implementation of the new scheme (Ieromonachou *et al.*, 2004, p. 83).

Perhaps the limited insights that the SNM literature affords on the role of the network manager, as opposed to the public policy function, has something to do with the professional orientation of the principal SNM writers. Their main preoccupation appears to be with the creation of niches and the inducement of regime shift from the public policy point of view. Yet, they do lay claim to a wider applicability of their approach: "We wish to emphasise that strategic niche management is not just something for governments: industry and NGOs are well placed to initiate and run niche projects (Kemp *et al.*, 1999, p 198). While we agree with this point in principle, it is clear that the practical aspects of how to do niche network management require to be spelled out more concretely in order for the approach to reach its full potential. We revisit this point in the next section.

A final recommendation for successful niche formation is to *keep the momentum* going. Raven, who compared different experiments in the field of biomass utilisation, noticed that the more successful ones were characterised by a continuous development pattern, whereas a discontinuous trajectory was visible in the case where no new market niche emerged. He concludes that it is important to ensure continuity in the learning process, in order to avoid losing important lessons for future use (Raven, 2005, p. 253-254).

Step 4: Scaling up of the experiment

The main preoccupation of the SNM researchers has clearly been on the initiation and management of niche creation. Little attention has been given to the stages where a clear technological niche has been developed, and the main task is shifting to the creation of a viable market niche. Weber *et al.* merely advise to "Look for opportunities to replicate an experiment and try to keep the experiences stored in a network" (1999, p. 53), and to customise the innovation when the pioneer market turns into a mass market (p. 55). Kemp *et al.* even seem to suggest that the preceding niche process has created the necessary conditions for the subsequent successful commercialisation of the innovation: "Apart from demonstrating the viability of a new technology and providing financial means for further development, niches helped to build a constituency behind the new technology, and to set in motion interactive learning processes and institutional adaptations -- in management, organisation and institutional context -- that are all-important for the wider diffusion and development of the new technology." (Kemp *et al.*, 1998, p. 184). However, it is widely known from marketing literature that such necessary conditions created in the R&D process are usually not sufficient to ensure successful market development in the next stage. The market creation process has its own dynamics, and different expertise and resources need to be brought in, in order to take the innovation forward towards a marketable product. This, then, seems to be another area in which SNM lacks detailed guidelines.

Step 5: Breakdown of protection by means of policy

Just as little has been written about the final stage, the dismantling of the protected space. Kemp *et al.* (1998, p. 188) and Weber *et al.* (1999, pp 55-58) observe that this should be done gradually, in order to avoid disruption of the ongoing processes. There are two clear circumstances in which protection must be withdrawn. Firstly, when it has become evident that the prospects for the new technology are not good enough so that it is unlikely to become financially viable, continued protection will be wasteful. A better option in those circumstances is to try to utilise the network that was formed for more

promising fresh experiments. Protection should also be withdrawn in the opposite case, when a newly developed technology with good market prospects is ready to be exposed to market discipline. In the latter case, continued protection is wasteful, and likely to thwart or stall successful commercialisation (Weber *et al.*, 1999, p. 58). However, in reality the main difficulty is likely to lie in assessing the scenario correctly. Often, the case is not clear cut. When should an experiment be dubbed a success or a failure, in view of our experience that it can take decades for good workable prototypes of new technologies to emerge? Aside from this, political considerations (vested interests) are likely to play a major role in the decision process as well, making this stage a very tricky one. Many experiments with infant industry protection in developing countries have failed at this stage, either by not orchestrating and planning for an orderly and timely withdrawal of protection, or by underestimating the length and extent of the learning trajectory required.

The most likely reason for the SNM literature's limited discussion of these issues is that few SNM experiments have actually managed to get this far. However, important lessons could be drawn from other types of policy experiments outside the direct realm of SNM, such as the above-mentioned infant industry protection efforts. Alongside many failed experiments in Latin American and African countries stand major successes of technological maturation and catch up in East Asia. We will devote some attention to this issue in the next section.

Conclusions from the SNM review

Conducting a cross-cutting review of SNM studies clearly yields a more comprehensive insight about the niche creation process than the individual SNM studies are able to provide on their own. In our view, then, this kind of synthesis was sorely lacking at this stage of the SNM research, where a reasonable number of studies and experiences have accumulated. A second point to note is that the synthesis gives an adequate insight into several aspects of the niche creation process. In particular, a number of prerequisites for successful learning emerge, as well as a range of contextual factors that can facilitate and stimulate the process. One can also extract a number of guidelines on the practical management of the niche creation process. One can however identify three areas where more detailed knowledge and insight appear to be desirable: (a) the practical management of the actor network engaged in conducting the experiment; (b) the commercialisation of a successful technological niche technology; and (c) the policy management of the breakdown of protection.

4. Lessons from radical innovation studies

The literature about radical innovation yields a number of insights in the three above-mentioned aspects of management of SNM niche processes. The type of innovations that is the focus of that literature is in essence the same as the new niche technologies that SNM is concerned with: They are technologically radically new, as well as completely new to the market. The only difference between the two literatures is the perspective from which the innovation process is examined. SNM takes a 'meso' view, focusing on the level of the actor network, whereas writers about radical innovation study the strategic dynamics of innovation from a 'micro' (firm) perspective. However, there are obvious points of overlap, since modern innovation processes are commonly carried out in networks that extend well beyond a firm's organisational boundaries, involving customers, suppliers, partners, and even governmental bodies (Dicken, 2003). Studying a firm's radical innovation behaviour therefore inevitably entails an analysis of actor network dynamics.

4.1 The practical management of the actor network

One area on which radical innovation studies are a useful elaboration to the SNM literature concerns the different actors that are required to manage a niche process effectively. In the SNM review we encountered the innovation champion, who is characterised as an entrepreneurial person with visionary qualities, and whose active involvement in the niche process is crucial to its eventual success. From radical innovation studies we can learn that the championing role is more complex and differentiated, and that its different functions may often be vested in different people. For example, through detailed empirical research on 27 radical innovation projects Rice *et al.* (1998) identified the importance of technical, project, senior management, and business unit champions. Others speak of different

championing functions that are critical to the success of different types of innovation projects. What seems to work well is a combination of a hands-on project champion, combined from a promoter at a high level in the firm's hierarchy (Day, 1994). The project champion hails from the lower levels of the firm, from where the innovation emerges. He or she is close to the necessary sources of technological and market information, and has informal organisational power and influence that help him/her to build effective support coalitions. If necessary, such a person can let the project keep a low profile, so that its activities remain invisible to top management until the innovation can demonstrate success. In this way it avoids interference from the top and conflicts from powerful opponents that could frustrate the incubation process. Likewise this strategy avoids having to cope with pressures for quick results and obligations to absorb over-abundant resources at too early a stage.

The implication for SNM is that the major participating actors in the niche creation process are in themselves likely to constitute groups of heterogeneous individuals, which include people who function as champions in their respective organisations, and who function alongside an overall niche manager. The championing function in niches is therefore likely to be more complex than what SNM has revealed so far.

The radical innovation literature also makes suggestions about the tasks that these hands-on champions have to perform in order to promote learning in the actor network (or 'distributed learning'). Daily practice of community is important, through sharing expertise, talk, sociability, argument, disagreement, negotiation and so on. All these interaction processes serve to mobilise the network's creative potential. Regular games, competitive events etc., should also be conducted, in order to encourage the emergence of divergent views and ideas that can rub against each other (Wenger, 1998).

The role of top managers should be one of indirect management of these processes. They should put in place the right organisational structures, incentives and a good research climate, leaving sufficient flexibility for the project implementers to get on with their tasks ('orchestration'), endorse the innovative results that come up from within the organisation ('retrospective legitimising'), and act as mediators and decision makers in conflicts between project champions and critics ('judging and arbitration') (Day, 1994, p. 151). Even if top management is reasonably closely involved in nurturing a radical innovation project, it will not typically assume detailed championing functions such as the actual definition of the product or carrying out frequent mentoring and monitoring (*Ibid.*, 1994, p. 153). Their role is that of an organisational sponsor or 'patron', providing encouragement from high up in the firm's hierarchy, and ensuring financial backing that prevents premature closure of niche processes (McDermott and O'Connor, 2002). Others characterise this role as catalyst, encouraging, sharing and integrating (Bonner *et al.*, 2002). Top management must create a shared context and a sense of common purpose that informs an overall strategic direction in which the experiments must fit (Wenger, 1998). Projects that are subjected to too much direct control from top management have been found to suffer from delays, cost overruns, lower product performance, and lower team performance (Bonner *et al.*, 2002).

Another field in which the radical innovation studies add insights to the SNM literature concerns the composition of the actor network responsible for niche development. The SNM studies mention the need for a diverse range of social actors such as firms, NGOs, unions, producer associations, suppliers, and so on. The radical innovation literature goes beyond this, by emphasising the importance of diversity on the *individual* level within the actor network as well. Members should vary across race, gender, nationality, age, personality profile and experience. The greater the diversity, the greater the range of viewpoints and knowledge that will be brought to bear on the project (Lester, 1998). The more unfamiliar the market, the more important it will be to involve commercially-oriented R&D staff and senior management from participating firms, leading members of the technological community, experts from related markets, and potential users (Rice *et al.*, 1998).

Furthermore, people who join the niche network from the side of the participating firm(s) should form cross-functional teams (Bonner *et al.*, 2002; O'Connor and McDermott, 2004). A study tracking radical innovation teams spanning 12 projects in 10 large US-based firms found that teams consisted of five to six core members, each of which had an in-depth specialisation such as marketing, process engineering, or industrial engineering, as well as considerable amount of all-round knowledge (O'Connor and McDermott, 2004). The professional breadth of the core individuals is apparently crucial. They should have a wide knowledge of their company through having served in several different business units on rotation. This wide exposure is necessary for building a wide informal

network, both inside and outside their firm, which they can access at any time. This network enables them to get early signals about emerging business opportunities. It also saves considerable time and money by facilitating co-operation from colleagues and friends when it comes to performing tests, trial runs, or making information available. People with broad personal networks easily form 'communities of practice' across organisational divisions and the company's boundaries (McDermott and O'Connor, 2002). For obvious reasons such people have also been called 'boundary-spanning individuals' (Probst *et al.*, 1998) and innovation brokers (Nooteboom, 1999).

The core team members (at least those who join the niche network from the side of the firm(s)) should be dedicated to the innovation development project for at least fifty per cent of their time. If this requirement is not met, they are likely to suffer from task fragmentation and fall behind schedule, while those who can devote sufficient time to the project become disgruntled and frustrated due to lack of progress by the other team members. In addition to the core members, there is a role for resource persons who are less closely involved in the decision making process and need not be completely informed of all activities in detail. Typically, such people spend less than half of their time on the project (Lester, 1998).

The radical innovation literature also yields some important suggestions for the network manager, whose management role remained rather unspecified in the SNM studies. First of all, the manager must ensure that the participating team members are to be actively involved at an early stage at the determination of the project's operational controls such as goals, budgets and schedules (Bonner *et al.*, 2002). The manager should also organise regular professional conferences and meetings at which data are presented for the technological community's reaction, and to gain potential customer interest through early market probes. We will deal with market probing in more detail in section 4.2.

4.2 *The commercialisation of a successful technological niche technology*

From the emphasis that the SNM studies put on the early stages of niche creation, one might easily infer that the creation of a viable technological niche is by far the most difficult part of the process. Without denying the complexities arising at that stage, there are reasons to suggest that the subsequent process of *market* niche formation warrants more attention than it has received so far. With the help of radical innovation studies, two important dimensions of that process can be highlighted. The first concerns the question how firms manage the transition of a new technology from the R&D phase to the start of production operations. As Rice *et al.* (2002) found in a survey of 12 major radical innovation projects in large corporations, underestimation of the requirements of successful transition created several problems that can easily lead promising projects to fail. The key problem seems to be that many managers wrongly assume that radically new products can be commercialised by using the same tried and tested techniques and methods for market research as are applied to more incremental innovation.

Rice *et al.* (2002) argue that the transition should be a well-managed process in order to avoid projects from falling in between two stools. They recommend that the R&D unit (the sending unit) and the operations unit (the receiving unit) should assess the transition readiness by sharing information together. A separate transition team should also be established, composed of members from the R&D and the operations sides, as well as transition experts. This team should draw up a transition plan that lays out the tasks, timetable, roles and responsibilities of team members, and serves to guide the efforts of the team and provide a benchmark against which progress can be assessed. The transition team should organise continuous learning by undertaking regular market probes and analysing feedback. In addition, a transition oversight board should be created, composed of senior managers with organisation clout and knowledge of the transition process. Transition funding from corporate resources should be committed. The transition team should do the groundwork for a big market launch, while senior corporate managers should continue to assume championing roles at this commercialisation stage.

Other radical innovation authors provide insight into the nature of the marketing techniques that should be utilised during the transition phase. All these studies emphasise that conventional marketing techniques such as market surveys, focus groups and concept tests are quite useless and may even be misleading and counterproductive (Lynn *et al.*, 1996; Rice *et al.*, 1998; Leonard, 1998). Engaging lead users - which is advocated in SNM studies - is also in this category. As Lynn *et al.* (1996) argue, it

makes little sense to be customer driven when it is not yet clear who the customers are going to be. Lead user analysis is useful only when the new product can be somehow linked to existing products that users are familiar with. In the case of radical innovations, customers lack this frame of reference (Leonard, 1998, p. 190).

Rather, what is required are techniques that will help create a new market. Market probes are conducted by means of organising demonstrations of early prototypes in the organisations that form the firm's network, and organising potential customers' evaluations of early working versions. A Darwinian selection strategy entails experimentation with multiple models simultaneously, to find out which ones the market appears to value. Also well known is the conduct of a series of sequential market try-outs, 'probes', with early prototypes in different market segments. Each probe serves as a vehicle for learning about the new technology in its real life context, followed by adjustment in technology design and marketing approach. At the same time the exposure to early prototypes influences the expectations, needs and behaviour of potential customers. This experimentation and learning (also called 'product morphing') is an iterative process. Each probing and learning cycle strives to be "... a step closer towards a winning combination of product and market" (Lynn *et al.*, 1996, p. 19). Relevant for SNM is the fact that probing and learning not only occurs within the boundaries of individual firms, but that it also involves competitors. Some firms practice vicarious learning, waiting for a pioneer competitor to take the lead with market tests and learn from its mistakes. A similar idea underlies the SNM approach, which advocates the simultaneous establishment of several parallel experiments and niches focused on the development of alternative solutions for the same problem.

Marketing and distribution costs can be substantial, especially in the early stages when a dedicated network for the new technology does not yet exist. It may not always be feasible to build an extensive new distribution network right from the beginning of the marketing effort, when the probing process is still going on. A potentially interesting way to get around this problem is to try to team up with manufacturers of established products that are in some way complementary or related to the new product, initially utilising their distribution and marketing channels (Heierli, 2000, p. 70). This kind of piggy-back arrangement can produce win-win situations. Translated into SNM language, this strategy amounts to utilising features of the incumbent regime as a starting point for the transition process. Another useful marketing strategy is to offer a variety of models of the new technology in order to attract a larger clientele in the initial stages, when demand for any specific model is still well below the threshold profitability level. Thirdly, adoption in small instalments could be advisable in the case of new products that are divisible, such as small-sized packages. In the case of non-divisible products, financial constructions such as hire purchase can have a similar effect of bringing the new technology within the financial reach of a larger customer group and reducing risk associated with large-scale adoption. All these methods can help to bring about critical mass which is needed in order to reach financial sustainability (Heierli, 2000).

4.3 *The policy management of the breakdown of protection.*

There is a great similarity between government policy for SNM projects and government policies for infant-industry protection. Infant industries embody technologies that are introduced into a specific national context for the first time, thus constituting novelties in that local context, even though they are already well established elsewhere in the world. For this reason, initial production tends to be characterised by all kinds of inefficiencies and problems. It can take considerable time, even decades, for an infant industry to become established and able to compete internationally. Moreover, maturation is not an automatic and costless process. It requires a non-negligible technological learning process driven by considerable effort. Effective learning can only occur when the infant is given temporarily protection from international competition (e.g., Bell *et al.*, 1984; Pack and Westphal, 1986). The need for this kind of incubation process is highly similar to the requirement for niche protection as advocated by the SNM authors.

We summarise key lessons from the infant industry policies applied in East Asia, notably Korea, Taiwan and Japan. In notable contrast to Latin American, African and South Asian countries, these countries have been highly successful in achieving maturation of successively complex technologies.

Their experiences offer useful insights into the policies for niche promotion and the way in which withdrawal of protection has been managed.

The success of the infant industry policies in the East Asian countries has been documented extensively and does not need further justification here (e.g., Lall, 1992; World Bank, 1993, Page, 1994). The general principles of the support model adopted were essentially the same in the different countries. It consisted of a large variety of incentive policies that were always conditional upon the recipients meeting strict performance standards (Wade, 1988 and 1990; Amsden, 1989; Won, 2000). Amsden (1989) observes that such reciprocity in the relationship between the state and firms was highly effective: the more reciprocity, the higher the speed of growth (pp. 145 -47). These carrot and stick policies were mutually coherent and mutually reinforcing. This required close central co-ordination among different agencies and ministries in charge of different support instruments and functions. The overall orchestration of this 'well oiled machine' was performed by powerful governments that formulated strong long term industrialisation strategies that provided overall priorities and consistency. The detailed implementation was delegated to competent and well remunerated bureaucracies that maintained close contacts with firms and other interest groups in the private sector, but that were at the same time relatively resistant to rent seeking and lobbying by these parties (Wade, 1988, 1990). All countries exhibited a high degree of co-operation between government bureaucrats and managers of private enterprise. Governments pressed private sector actors to form organisations such as industry associations and co-operative bodies, which could function as central actors in the communication and negotiation with equally well organised bodies representing government. Each country had one very powerful central government body at the top of the government hierarchy, which assumed a very active role in promoting science and technology development. In Japan this was the Ministry of International Trade and Industry (MITI), in Taiwan, the Industrial Development Board, and in Korea the Council for Economic Planning and Development. Thus, institutional structures were formed to facilitate continuous public-private dialogue and consultation. For the governments this mechanism was essential to be able to monitor the firms' learning progress, so that policies could be adjusted in line with performance. Withdrawal of protection was managed accordingly, in gradual fashion. This close consultation and monitoring, together with the strictly conditional terms on which support was provided, were the main mechanisms used to ensure that protection would be temporary. In stark contrast with other developing countries in Africa, Latin America and South Asia, where protection tended to be provided without strings attached and without time limit, East Asian government signalled the temporary nature of the support to private actors right from the start, and the whole incentive structure was geared towards gradual withdrawal (Wade, 1988). Undoubtedly this was crucial for creating the right expectations and behaviour among the support recipients.

While each country adopted a somewhat different set of policy instruments and used different institutions, reflecting national differences between them, the general thrust of the support model was the same. For example, in Taiwan, considerable emphasis was placed on internal competition among the many small and medium sized family businesses that are the dominant form of Chinese business. In contrast, in Korea a limited number of large firms (*chaebol*) were heavily promoted. These were pressed to meet increasingly ambitious annual export targets and were thus forced to cope with international competition. Thus, both countries made use of competitive pressures, but in different ways that suited their unique culture, and economic and social characteristics (Lall, 1996, pp 62-63). An elaborate list of all kinds of incentive policies and the conditions attached to them is provided in Wade (1990, pp. 113 - 195). A few representative examples are the following:

In the area of financial control, the East Asian governments placed heavy emphasis on credit-based systems, while discouraging the development of domestic stock and bond markets. In this way, by assuming control over the banking system, the governments could exercise considerable influence over borrowing by firms for technology investments. They penalised irresponsible borrower firms by refusing to keep bailing them out. They also selectively directed credit on favourable terms to specific firms targeted for promotion, by underwriting risky bank loans to these firms. Conditions attached to research funds emphasised collaborative ventures between private sector players, universities and research institutes.

In the field of trade policy, extensive use was made of selective import controls such as tariffs, quota, and conditional permission to import. These mechanisms served to stimulate increased contacts

between purchasing firms and potential local suppliers of machines, equipment and components. The mere threat by government bureaucrats of allowing purchasing firms to import would put sufficient performance pressure on local suppliers to make the effort to deliver an equivalent item at a price that was not too far out of line with the international import prices. By applying this rule to successively complex items, local suppliers were forced to keep upgrading continuously. Trade instruments in the form of export credits and underwriting of export risks were also pervasive. Again such support would be withdrawn quickly if firms failed to meet their export targets.

Foreign direct investment regulations were also used. All three countries preferred to nurture national firms, not permitting foreign investors to enter strategically important sectors. This was done in order for the governments to be able to exercise more control over the firms and their financing.

In addition there were a host of fiscal schemes such as tax exempt technology development funds; tax credit for R&D expenditures; tax credits for upgrading human capital related to research and setting up industry research institutes; accelerated depreciation for investments in R&D facilities; tax exemptions and reduced import duties for key imported research equipment; and reduced excise tax for technology intensive products. Last but not least, governments used administrative guidance and persuasion to coax firms to keep improving, and supporting private sector players through state-financed research and service organisations. For example, the Korean KETAC helped firms to commercialise new products (Lall, 1996).

It is clear the economic conditions in which the East Asian countries nurtured their infant industries over the past decades are very different from the economic environment of today. Governments are currently no longer in a position to use extensive regulation of trade, finance and foreign investment under current WTO agreements. However, it is still possible to draw some more general lessons from the East Asian experience. Support to niche players is likely to be most effective if it comes with clear targets and penalties that are enforced when these targets are not met. The targets should become increasingly ambitious over time. These rules of the game should be communicated clearly right from the start of the SNM process, so that the stakeholders' expectations are aligned in this direction, and they will not waste energy in pursuing rent-seeking activities. Furthermore, a government may be able to exert more leverage when it decides to select smaller national firms as leading players in the SNM niche process. Big TNCs have deep pockets and do not need to rely in any way on subsidies provided by a government in one particular country. Moreover, governments could try to promote collaborative research initiatives by the niche participants by attaching relevant conditions to their funding and other support.

5. Conclusions

Pooling the individual SNM studies in a cross-cutting review has yielded considerable added value. A number of prerequisites for successful learning emerged, as well as a range of contextual factors that can facilitate and stimulate the process. In addition it became possible to extract a number of guidelines on the practical management of the niche creation process. However, we identified three weak areas. These gaps were filled with insights from additional literatures on radical innovation and learning in infant industries. The main new insights are as follows:

The management of the niche process: Different stakeholder categories are likely to constitute groups of heterogeneous individuals in themselves. Each stakeholder group has people who have to function as champions in their own organisations, and function alongside an overall niche manager. In order to keep everyone together and stimulate maximum learning, the overall niche manager should practice community-building through sharing of expertise, talks, sociability, arguments, disagreements, and involvement in negotiation, games, competitions, and so on. Early-stage involvement of all the participating team members is essential. Moreover, the manager should organise regular meetings at which data are presented for the wider technological community's reaction, and to gain potential customer interest through early market probes. Top managers of the companies that participate in the SNM experiments should ensure indirect support, by putting in place the right organisational structures, incentives and a good research climate, whilst leaving sufficient flexibility for the cross-functional teams that participate in the actual experiment. Both niche managers and top managers of the participating companies must ensure diversity of participating people in SNM experiments across race, gender, nationality, age, personality profile and experience.

The commercialisation of a successful niche technology: The party that will ultimately bring the new technology to market must ensure a smooth hand-over from R&D experiments in the niche to their marketing department. It is useful to manage this transition as an organised activity and assigning responsibility to a specific transition team. That team should organise continuous learning by undertaking regular market probes and analysing feedback. At this stage, conventional marketing techniques, including engaging lead users (as recommended by SNM) are not suitable, because one cannot be customer-driven when it is not yet clear who the customers will be. What is needed are sequential market probes or 'product morphing' through organising demonstrations of early prototypes in the organisations that form the firm's network, and organising potential customers' evaluations of early working versions. Marketing techniques designed to overcome problems of high costs in initial small markets include: teaming up with manufacturers of established products that are complementary or related to the new product for the use of their distribution and marketing channels; offering a variety of product models in order to attract a larger clientele; offering small trial packages; or hire-purchase in the case of non-divisible products.

The policy management of the breakdown of protection: Support to niche players is likely to be most effective if it comes with clear targets that are increasingly ambitious over time, and penalties that are enforced when these targets are not met. These rules of the game should be communicated clearly right from the start of the SNM process. Furthermore, a government may be able to exert more leverage when it decides to select smaller national firms, rather than big TNCs, as leading players in the SNM niche process. Moreover, governments could try to promote collaborative research initiatives by the niche participants, by attaching relevant conditions to their funding and other support.

All the above conclusions constitute suggestions to be tried out in SNM experiments in practice. This will hopefully bring SNM one step further towards a more operational tool for developing successful novel technologies.

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