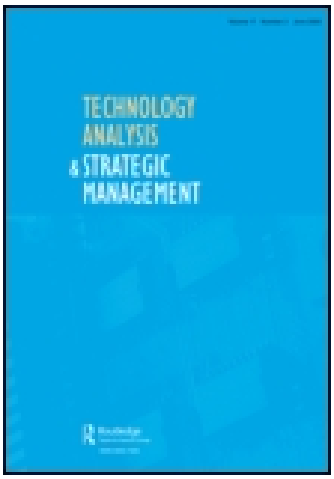

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Systemic transformation, anticipatory culture, and knowledge spaces: constructing organisational capacities in roadmapping projects at VTT Technical Research Centre of Finland

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This article suggests that, in the current interlinked innovation meta-system, research and technology organisations (RTOs) would benefit from developing two systemic capacities: partial structural openness enabling flexibility in organisation and an anticipatory culture that builds on an anticipatory agency, that is, a proactive participatory approach that leads to action. In this article, we explore the questions of systemic transformations and the building of an anticipatory culture in the context of VTT Technical Research Centre of Finland. First, we discuss the strategic development paths, anticipatory culture and systemic transformation capacities in the context of RTOs. Second, we show how process-based roadmapping can be applied in building the systemic transformation capacities and anticipatory culture. Third, we illustrate these notions by analysing four roadmapping projects as case studies.

Keywords: systemic transformation; capacity; research and technology organisation (RTO); anticipatory; agency; culture; roadmapping; strategy process

Introduction

The geographical scales of innovation systems are currently more interlinked than ever. The interrelatedness poses specific challenges for an organisation striving to navigate in this landscape. Navigation calls for at least two kinds of strategic capabilities: the capability to determine one's current position in relation to streams passed, and in relation to other entities, and the capability to anticipate one's future position in relation to streams that could emerge, and in relation to potential positions of other entities. In short, an organisation faces a situation that we here call a systemic-temporal paradox: strategies should simultaneously be based on a 'culture of inertia', on the historical paths, and on a 'culture of swiftness', on the constantly forming potentialities of the

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future. Hence, our article starts with a question of how to foster these kinds of strategic capabilities in an organisation. We propose that this systemic-temporal paradox could be tackled by fostering two systemic capacities: (1) partial structural openness in the organisational structures and (2) an anticipatory culture that builds on an anticipatory agency, that is, a proactive participatory approach that leads to action.

In the article, we focus especially on research and technology organisations (RTOs). As argued by Arnold, Clark, and Jávorka (2010, 9–10), there are many definitions of RTOs. They (2010, 10) use the following definition: RTOs are organisations whose predominant activities are to provide research and development, technology, and innovation services to enterprises, governments, and other clients. Arnold, Clark, and Jávorka (2010, 7) assert that RTOs play important roles in the European innovation system and in *de facto* European Research Area policies, especially by increasing the innovation activities in industry through technology platforms, stretching technological capabilities of companies, and connecting research-based theoretical knowledge with practical knowledge through applications.

We explore the questions of systemic transformations in the context of Finnish RTO, namely VTT Technical Research Centre of Finland, and propose that principles of roadmapping could be applied in building the systemic capacities. We use a notion of process-based roadmapping that widens the horizons of traditional technology roadmapping in such directions as visionary strategic management, network building and development, and organisational learning. We realise this by specifying the knowledge spaces and scopes related to roadmaps. After that, we demonstrate the 'widened' roadmapping approach by using four of VTT's foresight projects as case studies.

The article proceeds through five sections. Section 2 briefly outlines strategic development paths in an RTO and discusses the idea of anticipatory culture and its relations to systemic transformation capacities. Section 3 presents the notion of process-based roadmapping that is based on the identification of knowledge space and roadmap scope. Section 4 presents four case studies of VTT's foresight projects. Finally, Section 5 wraps up the argument and opens future avenues for further exploration.

Strategic development paths and systemic transformation capacities

An important starting point when building an anticipatory culture is the realisation that organisations act under constant temporal tension. There are three basic temporal levels that condition the strategic development path of an organisation: (1) the future development options in the context of anticipated and unknown challenges, (2) the past decisions that affect the organisation either explicitly or implicitly, and (3) the present, in which all the actions and decisions are put into action. It is critical to understand that the unrealised options in the past, as well as the potential ones in the future, also affect the present decisions.

The idea of an anticipatory culture builds on this temporal tension (Figure 1). Therefore, the adoption of an anticipatory culture does not mean that historical development paths are erased, but in fact quite the opposite: an anticipatory culture, as we propose it, calls for understanding of historical paths in an organisation. Every organisation is faced, from time to time, with strategic watersheds – decision moments when the organisation has to visit its fundamentals and ponder whether it is going to continue with business as usual, try modest renovations, or change its logic completely. In the process, some path gets chosen, either explicitly or implicitly, and the realised path then leads either to growth, even development or decline.

It is important to realise that not only the realised paths affect the present development and the future possibilities, but the unrealised options also 'haunt' the present in the organisation's

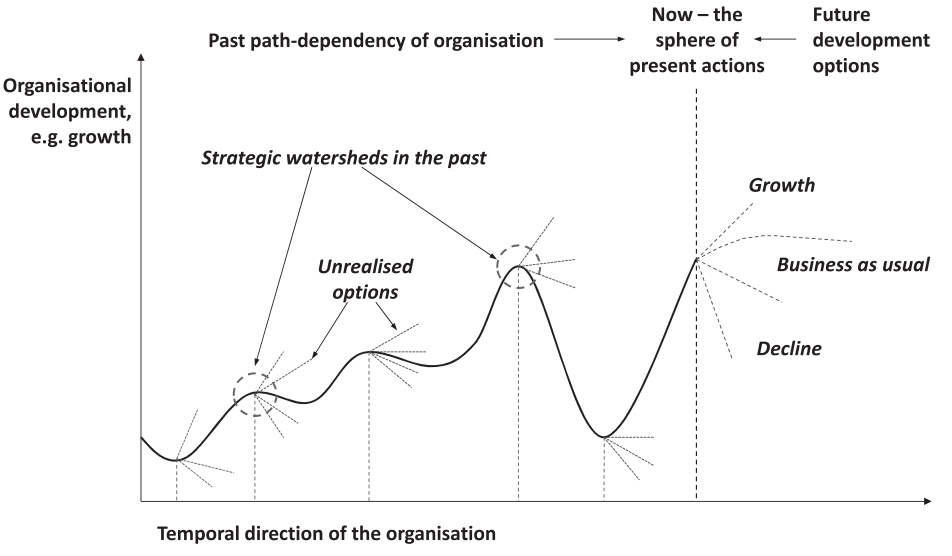

Figure 1. Interplay of past, present, and future knowledge in an organisation.

memory, at least to some extent. The causality between decisions made and paths realised is not always linear: in other words, it is not always certain that the decisions made and the paths realised correspond. In fact, it could be suggested that most of the decisions are realised only partially. Therefore, it is crucial to conceptualise an organisation not as a closed node in the present, but as a kind of continuum that is constructed out of future options, the present, realised path in the past, decisions made in the past, and unrealised past options.

Organisations navigate, as argued above, in the strategic landscape that increasingly requires specific systemic capacities. In the relevant literature, the innovation activity, and indeed the entire activity field of organisations, has been conceptualised as relational practices, that is, as activities realised in relation to impulses stemming from users, other organisations, and wider currents at the level of the strategic landscape. For example, Smits and Kuhlmann (2004, 11) argue that innovation is a systemic activity that 'involves a variety of actions within the system, of which the innovating organisation or innovator forms part'. In addition, Geels (2004, 900) uses the term 'socio-technical system' to describe the systemic interaction that encompasses production, diffusion, and the use of technology.

In this article, we open a view towards the *systemic* capacities, based on a perspective of an organisation as a *complex system that is mobile in space–time*. This means that the sphere of potential actions in an organisation is relational to the specific knowledge spaces (see the following section), and is conditioned by historical paths and potential future options manifested in the organisation's present. We realise that transformation capacities could also be identified on other grounds, for example, from emphasising managerial performance or the efficiency of production processes. Thus, our take on transformation capacities is conditioned by our systemic lens: the use of other lenses could accentuate different sets of organisational capacities.

We argue for systemic transformation capacities based on the systemic-temporal paradox depicted in the introduction: strategies should build on robust historical paths, and they should also foster future-oriented adaptability. We propose that this paradox could be tackled by fostering two systemic capacities: (1) partial structural openness that endorses flexibility in the organisational

structures and (2) an anticipatory culture that builds on an anticipatory agency, that is, a proactive participatory approach leading to action. In this situation, strategies should be constantly 'on the move', and based on 'future beacons' that are locked only temporarily. The position of these beacons should be regularly checked in relation to changes in the landscape and in relation to other 'navigators'.

The first component of the systemic transformation capacities, enabling the mobile strategies, is a partial *structural openness* that endorses flexibility in responding to the systemic flows, such as changes in the business environment or in the customer's innovation processes. The idea springs from the perspective that organisations are complex systems where transformations arise through emergence, by interactions of multiple actors and trajectories working in different temporal dimensions. These dimensions could be, for example, linear, visionary or disruptive. At the strategic level, the structural openness enables the combination of these different temporal dimensions. For example, Aaltonen (2007) calls these places of combination 'chronotope spaces'.

The second component is a horizontal *anticipatory culture* that connects the critical knowledge in an RTO. The anticipatory culture is catalysed by an anticipatory agency. An *anticipatory agency* can be defined as a strategic ability of an organisation to construct feasible targets for the future through shared dialogue, and to implement actions on this basis. The notion thus combines organisations' capacity to monitor their environment, to make future-oriented strategic conclusions on this basis, and to turn these conclusions into actions. One could also talk about a 'developed' anticipatory agency as an anticipatory capacity, that is, as an organisational capability to continuously reflect on one's own actions against systematically formed strategic views of the future, and to change one's behaviour and/or strategic view of the future when necessary.

Roadmapping as a frame for constructing systemic transformation capacities

Roadmapping, strategy processes, and capacity building

We suggest that roadmapping is a felicitous method for fostering and steering systemic transformation capacities. This is because roadmapping, especially in its strategic form (see below), is an adaptive process-based methodology well suited for systemic contexts (see Ahlqvist, Valovirta, and Loikkanen 2012): its visual format enables the transparent formulation of visions with explicit linkages across the temporal spectrum (present, medium term, and long term) and roadmap layers (such as drivers, markets, and enabling technologies). In the systemic context, roadmapping refers to a continuous and transparent process, not a single exercise, which produces a hermetic chart of the future with a sealed vision. Therefore, the vision should be understood as temporarily locked target that is systematically verified and re-formulated, either based on an organisation's strategy clock or when a critical need, such as a change in the environment, emerges.

In the context of systemic transformation capacities, the generic process of roadmapping is coarsely the following: (1) constructing an initial roadmap with a future vision and required temporal axes (short term, medium term, and long term), (2) translating the critical parts of the roadmap into action points, and (3) revisiting the roadmap periodically, varying roughly from a few months to 2 years. In these checkpoints, the roadmap is assessed against the changed circumstances. Process-based roadmapping is a scalable method that can be used to study the micro-level – for example, employees could even make their personal roadmaps – and the macro-level systemic interactions – for example, when roadmapping the futures of a national innovation system. The temporal spans of the roadmaps are also scalable, and should be fitted according to the theme. For example, the long term in the context of a highly dynamic field, such as mobile

information and communication technology (ICT), differs vastly from the long term of a highly inert field, such as transportation infrastructure. Roadmapping can thus be considered a kind of 'fractal' approach, which is scalable both temporally and substantially.

In addition, several other aspects make a further statement for roadmapping. First, roadmapping enables the organisation to systematically produce its own strategic future manuscript and set it in the context of organisational knowledge spaces (see the next section). These kinds of future manuscripts could also be produced with other narrative foresight methods, such as scenarios or 'genius forecasting'. Second, the roadmapping process enables the engagement of the key actors in an organisation. Thus, it builds on a variety of organisational knowledge spaces and advances commitment. Third, the roadmapping process enables the alignment of a common vision, the knowledge spaces, and temporal spans. To engage in a successful roadmapping process, the organisation does not only need to depict its present position, conditioned by historical paths, as transparently as possible (structural openness), but it also needs to promote an explicit anticipatory agency that is built against explicit future visions. Thus, the roadmapping exercise simultaneously fosters an anticipatory culture and structural openness through a systematic process and explicit visionary narrative. Fourth, roadmapping enables organisations to align their future visions with explicit action steps and to iterate the process systematically.

The theoretical background for the above formulations stems from the notion that roadmapping can be considered both as a line of strategic thought and as a process methodology.[1] Roadmapping combines different modes of knowledge with specific activity layers (Kostoff and Schaller 2001; Phaal, Farrukh, and Probert 2004). In other words, roadmaps are tools for the combination of organisational knowledge that may be 'unlinkable' with other strategic methods (see e.g. Petrick and Echols 2004; Phaal, Farrukh, and Probert 2006). As a process methodology, roadmapping consists of several modules. Modularisation allows one to form a tailored 'response chain' to answer different kinds of research and development problems (see, e.g. Lee and Park 2005). Modularisation also makes space for the combination of different foresight methods (Ahlqvist et al. 2007a, 2007b; Ahola et al. 2010). Furthermore, modularisation enables the tailoring of the roadmapping process to suit the needs of the different actors and different tasks in the innovation network (see Könnölä et al. 2009).

It is possible to make a distinction between two roadmapping cultures. First is the *culture of technology roadmapping*, in which the roadmapping is approached as a normative instrument to identify relevant emerging technologies and to align these technologies with explicit product plans and related action steps (see e.g. Phaal, Farrukh, and Probert 2001). In this culture, the roadmapping process is a tool to endorse product development. Second is the emerging *culture of strategy roadmapping*, in which the roadmapping is perceived more as a dynamic and iterative *process* that produces weighed crystallisations, usually in a visual form, of an organisation's long-term vision, and short- to medium-term strategies to realise this vision. Here, we call this methodology process-based roadmapping. It is based on an idea that roadmaps are like visual narratives describing the most critical paths of future developments (Phaal and Muller 2009). This visual emphasis enables the use of roadmaps as *crystallised strategy charts* that open simultaneous perspectives both on macro-level currents and micro-level developments (see Blackwell et al. 2008).

This idea of a roadmap as a crystallised strategy chart separates roadmapping from other 'generic' foresight methods, such as Delphi or scenario processes. Roadmapping can be considered as a meta-level visualisation of an organisational strategy that could utilise the inputs from Delphi or scenario exercises, just as Delphi or scenario exercises could utilise inputs from roadmapping exercises. Conceptualised in this way, roadmapping comes quite close to system dynamic modelling techniques, yet roadmapping is still more of a technique for strategic focussing

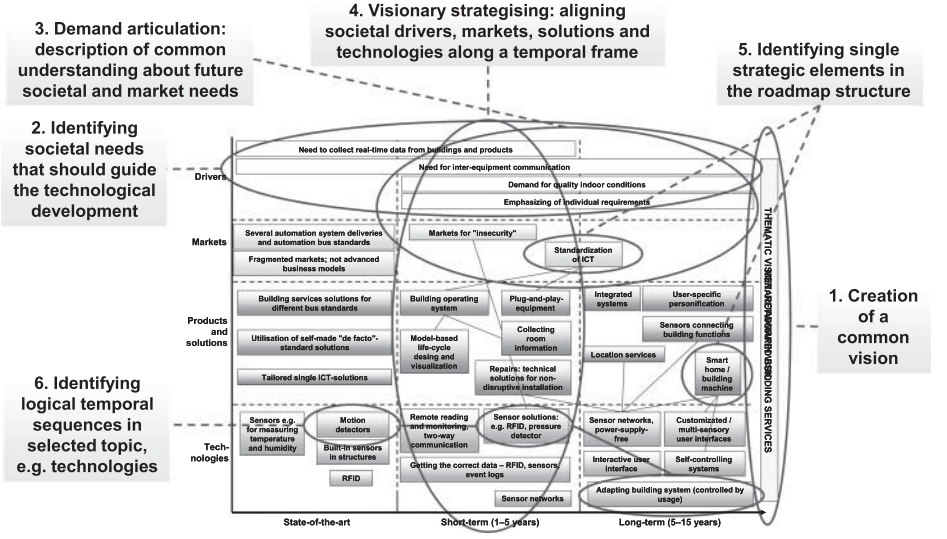

Figure 2. Using roadmaps in strategy processes (Ahlqvist 2009).

than for system simulation. However, combining roadmapping with system dynamic modelling is definitely a potential path for future methodological development.

Process-based strategy roadmapping is methodologically more flexible and exploratory than traditional technology roadmapping. The roadmaps are not approached as hermetic plans to achieve definite goals (e.g. new products), but instead they are approached as knowledge umbrellas that, by integrating different analytical methods, produce a visual strategy manuscript for an organisation. Strategy roadmapping is also about engaging and empowering people (see Ahlqvist et al. 2010). This idea links strategy roadmapping to organisation and strategy studies, especially to strategy crafting (see e.g. Heracleous and Jacobs 2008; Whittington and Cailluet 2008). Therefore, the emerging culture of strategy roadmapping should not be viewed as a 'pure' foresight methodology, but more as a hybrid of foresight and organisational strategy crafting.

Roadmapping can be used in strategy processes, for example, in the following ways (Figure 2):

- The first way is the building of a *common vision*. Basically, roadmapping is a collaborative long-range strategy process.
- The second way is the identification of *societal needs* as drivers for the design of solutions. When there is a need to link technological and societal trajectories, roadmapping is an apt instrument.
- The third way to use roadmaps is to *articulate demand* in the context of, for example, a product or a service.
- The fourth way is what we call *visionary strategising*. This means that one tries to understand the systemic linkages between roadmap layers, such as linkages between societal drivers, markets, solutions, and technologies in a certain time frame.
- The fifth way is to *identify single targets* in the roadmap structure. Single targets could be useful, for example, for making a subcontractor strategy.
- The sixth way is to read roadmaps as *temporal sequences*, that is, to identify logical temporal sequences in a specific roadmap layer, such as enabling technology.

In process-based roadmapping, systemic transformation capacities can be built through the following three steps: (1) identification of relevant knowledge spaces, (2) specification of the relevant roadmap scope, and (3) building a managerial orientation to deal with the results. These ideas and concepts are elaborated below.

Knowledge spaces and roadmap scopes

How is it possible to combine the roadmapping methodology with the creation of structural openness, an anticipatory agency, and an anticipatory culture? In order to realise this, we propose a model that separates roadmap knowledge spaces from the roadmap scope. Here, the *knowledge space* refers to a sort of niche in an organisation, in which an anticipatory agency can be mobilised. Knowledge spaces, therefore, depict key spheres in which the systemic transformation capacity is realised. The *roadmap scope* (below) refers to the level at which the roadmap is aimed. Scope is a more traditional insight into roadmapping methodology that separates, for example, technology roadmaps and market roadmaps. Our model separates roadmaps with R&D scope and roadmaps with systemic scope.

Figure 3 shows an ideal model of roadmap knowledge spaces. In the figure, we have singled out four knowledge spaces that are important in the context of RTOs (see also Table 1). The model combines the four knowledge spaces with three basic temporal scales (past, present, and futures). In the figure, the different 'modes' of temporal objects are depicted as irregular forms. The present, as the sphere of all actions, is the most coherent one, and the past and the futures are more incoherent. This visualisation underlines a crucial point: all three temporal scales are based on interpretation – that is, the actors have different interpretations of the present in relation to the past and the future – but the present is the only temporal position where interpretations can be turned into actions.

The first knowledge space is the *technology space*, which basically covers the domain of technical knowledge, emphasising technology as an object, that is, as a technological solution and a gadget, cutting through three temporal scales. The second is the *social/actor space*, which covers all the issues that are primarily dependent on relations between different social actors inside and outside the organisation. This space covers organisational development, markets, and also more

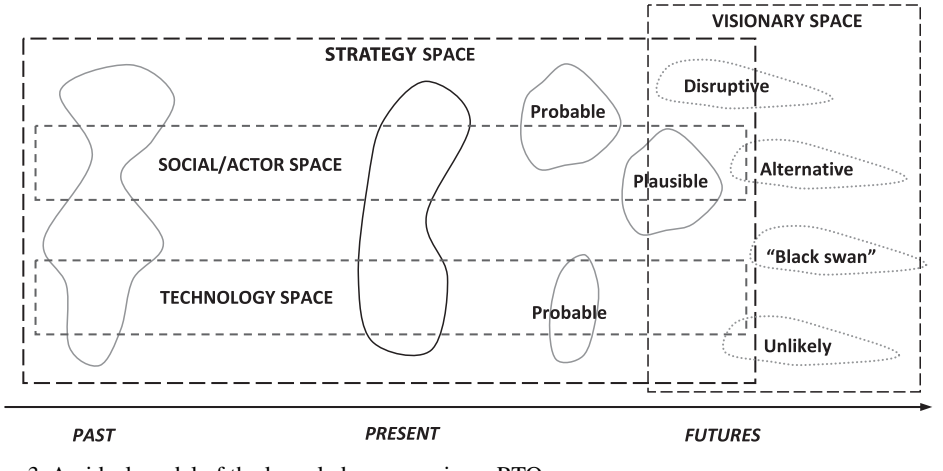

Figure 3. An ideal model of the knowledge spaces in an RTO.

Table 1. Depiction of knowledge spaces.

Knowledge space	Description	Key systemic capacities associated with the space	Forms of project knowledge
Technology	Covers a certain domain of technical knowledge, e.g. different technologies, gadgets, and development, cutting through the three temporal scales	Capacities for the renewal of the technological basis: R&D, adoption, etc.	Building a technological vision Scoping new enabling technologies or new products Identifying temporal sequences Identifying singular elements, such as separate technologies, applications, and solutions
Social/actor	Covers issues that are primarily dependent on relations between different actors inside and outside the organisation	Capacities for aligning development activities with societal drivers Capacities for market creation or entering into existing markets as a novel player	Building a market vision Identification of novel market features and actors Articulation of demand Identifying societal and market drivers
Strategy	Strategic and holistic view of the research objects Technology space and social/actor space are linked to a strategic perspective of the future, i.e. a strong target	Strategic capacity of the organisation and/or entity Building strategic transparency Communicating strategic aims	Holistic roadmaps to be used in long-term strategic planning Building synthesising vision (vertical and horizontal) Visionary strategising Aligning roadmap knowledge
Visionary	Exploration of futures on different scales of certainty	Systemic openness towards future possibilities Capacities for resilience	Drafting novel concepts Identifying wild cards Focusses primarily on vision building: BAU vision, disruptive visions, and improbable events

Note: BAU, business as usual.

macro-scale societal phenomena (drivers and megatrends). It should be noted that the differences between the technology space and the social/actor space are mainly heuristic, because technologies are formed in social interaction, and markets are created by socio-technical relationships. In the context of an RTO with an emphasis on technology development, this separation is, in our view, useful because it enables the organisation to set specific targets both for technologies as solutions and organisational actors as realisers of these solutions. Thus, our model presumes that there is a 'scale continuum' on which technological development can be interpreted: at one end of the continuum there is technology as a mere object (a solution), and at the other end there is technology as socio-technical constellation combining the technological object, related subject positions (e.g. developer, user, non-user, early adopter, latecomer, and experimenter), and the wider social settings (e.g. geographical, organisational, political, economic, and ethical).

In our model, the knowledge space that analyses these wider socio-technical constellations is the *strategy space*. This space takes a holistic view of the organisation and approaches it simultaneously as a socio-technical complex and as a strategic entirety. In this space, the technology

space and the social/actor space are combined in a distinctive strategic perspective. The fourth knowledge space is the *visionary space*. This space is devoted to the exploration of futures on different levels of plausibility. Our model starts with a presupposition that in the technology and social/actor spaces, the exploration of the more radical futures is usually restricted by the overall need to identify certain actions in the present. However, in the visionary space, the actual exploration of alternative futures is the core. In our ideal model, we have depicted, for example, disruptive futures (phenomena that change the name of the game), alternative futures (trajectories that are alternatives to the hegemonic futures), 'black swans' (utterly unsuspected phenomena that have significant impacts), and unlikely futures (futures that are not seen as credible, but that have significance in the imaginary of the present options). Table 1 translates the above-mentioned knowledge spaces into 'roadmapping language' and terminology. It describes the basic aims of the process and provides some views on the use of roadmapping material.

Table 2 presents the roadmap scopes in a schematic form. The first roadmap scope is *R&D I*, with a perspective of a single technology or object. This is quite a traditional technology roadmap that aims to build a future perspective for a single technology. The aim of the roadmap is to identify specific action steps towards the future. This scope is parallel to the technology space. The second roadmap scope is *R&D II*, with a perspective of a single organisation or firm. Basically, the view is similar to the first one, but instead of a technology domain, the focus is on the organisational

Table 2. Ideal scopes of roadmaps.

Roadmap scope	Description	Process aims	Primary use of the roadmap
R&D I: R&D perspective on a single technology or object	Roadmapping single technologies from a certain perspective	Enhancing organisational capacities in a certain technology field	Building vision and associated steps mainly in the technological space Drafting *action steps* to advance the implementation of the technology in question
R&D II: R&D perspective on a single organisation or firm	Roadmapping organisational capacities in developing new competencies	Roadmap for developing organisational/firm capacities	Combination of roadmap knowledge spaces depends on the specific aims of the process Forming *practical organisational conclusions* on the basis of the roadmapping
Systemic I: business perspective	Network roadmapping Cluster roadmapping	Roadmap for developing capacities for a network or a cluster	Combination of roadmap knowledge spaces depends on the specific aims of the process Making *business decisions* on the basis of the roadmapping
Systemic II: policy perspective	Innovation policy roadmapping	Roadmap for developing synthesising policy perspectives for public actors	Combination of roadmap knowledge spaces depends on the specific aims of the process Forming *policy conclusions* on the basis of the roadmapping

structures. The third scope is called *systemic I*, and it emphasises the business perspective. The roadmap aims to develop capacities for a network or a cluster, and combines roadmap knowledge 'spaces', depending on the specific aims of the process. The aim is to endorse business decisions on the basis of roadmapping. The fourth scope is *systemic II*, with a policy perspective. It is constructed to produce synthesising policy perspectives for public actors. The aim is to form policy conclusions on the basis of roadmapping. This category also contains a methodology of innovation policy roadmapping (see Ahlqvist, Valovirta, and Loikkanen 2012).

In the following section, we use four examples of VTT's foresight projects to illustrate how roadmapping can be applied in constructing systemic capacities.

Four case examples

The brief case examples are positioned according to the four roadmap scopes and the relevant knowledge spaces described in the previous section. The aim of the case examples is to depict concisely how the systemic transformation capacities can be fostered by roadmap exercises combining different roadmapping scopes and knowledge spaces. The central outcomes of the cases are contained in the concise conclusions after the cases.

Building Services Roadmap: technology and social/actor space, R&D I scope

Our first example is a roadmapping process that is aimed to renew a line of organisational competence that is already rather well established at VTT. The aim of the process was to form an outlook of development directions in building services, its research needs and business potential to the year 2020 (Paiho et al. 2007). The building services roadmap was realised in three phases in 2006–2007. In the first phase, a large background review was completed. The second phase was the roadmapping (Figure 4). Roadmapping was realised in three consecutive workshops. The first workshop was about drivers and technologies. The second workshop considered the future markets, business potential, and actors in the sector of building services. The third workshop focussed on and verified the constructed roadmap drafts. The building services roadmap was constructed through two roadmap levels. The first level was a metaroadmap that crystallised the project's results. The metaroadmap formed an umbrella for the second level thematic subroadmaps.

Knowledge spaces and systemic capacities

The building services roadmap can be perceived as an R&D I type of technology roadmap that is aimed to contribute to the technology space and the social/actor space. The project roadmapped a single type of technology sector and thus endorsed the organisational capacities in this domain. It built a vision of the future and fostered action steps to reach that vision. The knowledge spaces of the project are summarised in Table 3.

The building services roadmap operated, first, in the *technology space*. In this space, the project formed a novel perspective of VTT's research on building services and focussed on future possibilities by emphasising ICT applications. It was aimed to build capacities for the renewal of VTT's technological basis by stressing the development of a more service-oriented approach. The project knowledge in the technology space was constructed by building explicit technology visions, such as a novel way to characterise building services, and identifying novel technological concepts, such as a virtual power plant and the 'black box' of a building.

The project also operated in the *social/actor space*. It underlined, first, markets for the adoption of novel solutions, such as integrated ICT. Second, it perceived the market as a platform for new

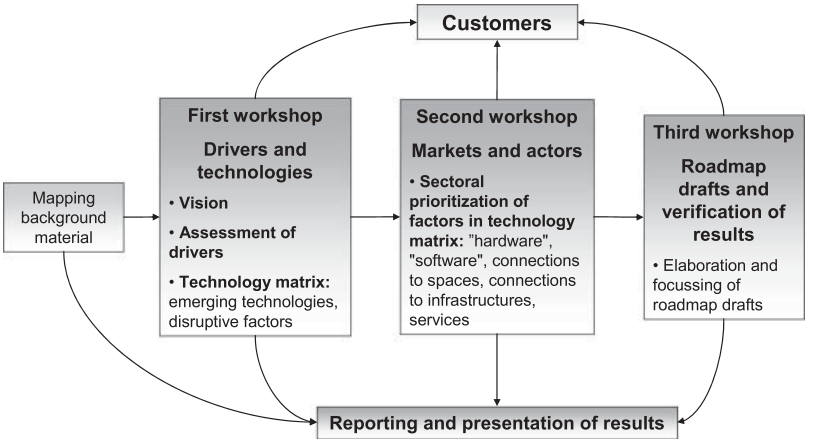

Figure 4. The roadmapping process in the Building Services Roadmap (Paiho et al. 2007, 10).

Table 3. Summary of the knowledge spaces in the Building Services Roadmap.

Knowledge space	Description	Key systemic capacities associated with the space	Forms of project knowledge
Technology	Exercise covered the field of building services with an explicit focus on the future possibilities, especially through ICT applications	Capacities for the renewal of technological basis internally at VTT Catalysing a new bedrock for building services in Finland by stating the VTT state-of-the-art in research	Technology visions were built, e.g. in a novel way to characterise building services New enabling technologies were identified, e.g. advanced materials Several novel single technology elements were embedded in the roadmaps
Social/actor	Exercise covered social/actor space from the selected perspectives Markets for adoption of novel solutions, e.g. integrated ICT	Capacities for linking of knowledge internally, e.g. construction and ICT Endorsed a view of VTT as a key player in the renewal of building services markets, e.g. spread the vision of technological possibilities for rather conservative markets in building and construction	In the exercise, market-based visions were built on the basis of current technology trajectories and also by tracking disruptive alternatives Novel market features and actors were identified, e.g. integrated service provider
	Markets for new services and service providers in the field	Built capacities for the construction of new integrated market players and clarified the role of VTT in relation to these new players	Articulated demand opportunities especially in the advanced building service solutions Identified societal and market drivers, e.g. customised housing and indoor services

services and service providers. In the social/actor space, the project aimed primarily to form capacities for linking knowledge internally at VTT, by combining construction expertise with ICT expertise. The project endorsed a view of VTT as a key player in the renewal of building services markets. It also enhanced capacity building for new integrated market players and clarified the role of VTT in relation to these new players. The forms of project knowledge were, for example, the identification of novel market features and actors, articulating demand opportunities in advanced building service solutions, and assessing societal and market drivers.

Service Science and Business network: strategy space and social/actor space, RD II scope

Our second example applies roadmapping in the context of an organisational development process aimed at establishing a service research network at VTT. Service research is an emerging field of research requiring cooperation across disciplines and the varied lines of business. In order to create the Service Science and Business (SSB) network, foresight and organisational learning methods were integrated in a workshop process. During the workshops in 2009, some 30 VTT researchers and management representatives built shared understanding of the field. The workshops were designed to facilitate dialogue between the users of the research, potential collaborators such as universities, funding agencies and the societal actors in the field of service science (Halonen, Kallio, and Saari 2010).

The process was based on a novel combination of methods. The integrative methodology rested on the model of expansive learning (Engeström 2001). In the process, two practical methods were added to the model of expansive learning. First, impact evaluation was used to gain a systematic view of the past (see Halonen, Kallio, and Saari 2010). Second, roadmapping was used to trigger participatory, future-oriented thinking. Roadmapping was divided into two phases. The first roadmapping phase traced the big picture of the service landscape from the present moment (2009) until 2025. This workshop was dedicated to identifying opportunities and challenges for service research in the long term; and to link, scale, and prioritise emerging service research issues. The second phase of the roadmapping was thematic, and it was carried out in five groups. This integrated process was called *learning by foresight and evaluation* (with the acronym LIFE, learning by foresight and evaluation; see Figure 5).

Knowledge spaces and systemic capacities

The SSB roadmap can be perceived as an R&D II type of technology roadmap that aims to contribute to the strategy space and the social/actor space. It roadmapped the potential for a novel development trajectory in an RTO (VTT) and it enhanced the organisational capacities of adopting a novel service science approach. The knowledge spaces of the project are summarised in Table 4.

The SSB network operated primarily in the *strategy space*. The project defined the emerging field of service research and its future possibilities, and clarified VTT's role in the context of service research. The project had an explicit strategic purpose of initiating a new 'service mind-set' in the organisation. It also strove to create structured openness for the creation of new service-oriented knowledge internally at VTT. Furthermore, the project aimed to fortify VTT's brand as a service research organisation by stating the VTT state-of-the-art and vision for the future. The forms of project knowledge that catalysed systemic transformation capacities were, for example, the production of different definitions of the 'service', the identification of the most important research needs, and the generation of project proposals.

The SSB network also contributed to the *social/actor space*. It identified the most important players in the field of service research internally and externally, and attempted to define markets

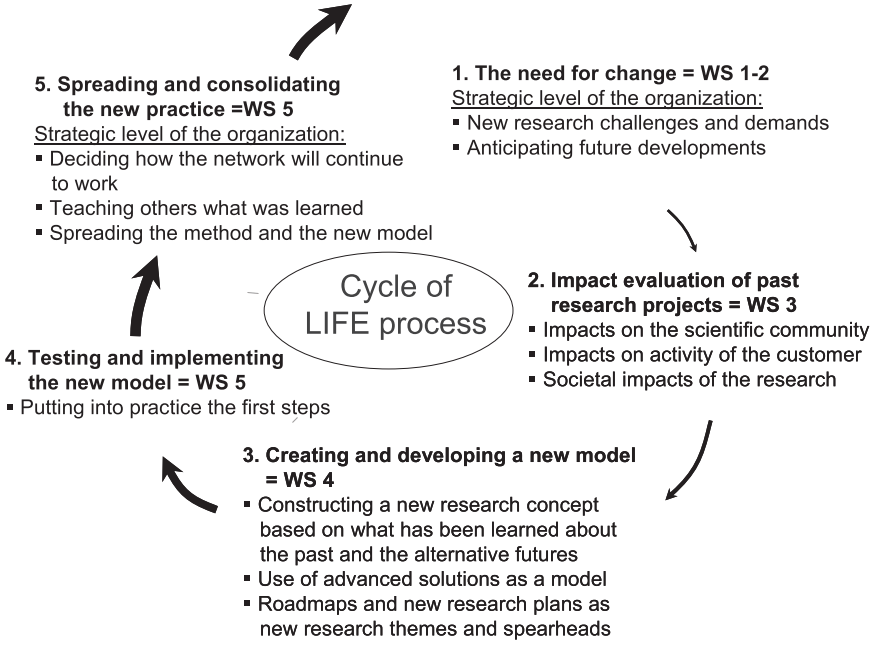

Figure 5. The LIFE (learning by foresight and evaluation) process.

for new services and service providers. In this knowledge space, the project fostered capacities for linking and sharing existing knowledge internally, and enhanced capacities for the creation of new knowledge in an emerging service science network. It also endorsed a view of VTT as a key player in service research in Finland and in Europe. The SSB network also had a strong capacity push that was built on the identification of VTT's own capacities, and potential future drivers for the services.

Construction Machinery Roadmap: strategy space and visionary space, systemic I scope

The third case is an example of a systemic network roadmap. The construction machinery roadmap was aimed to develop new service capacities for a network of technology-oriented companies, and to foster business decisions based on a novel 'service perspective' formed in the process (Myllyoja, Wessberg, and Pajakkala 2012). The project was realised in 2011–2012 by VTT and 10 companies represented the business network. The construction machinery was defined as machines, tools, and equipment that are used on the building site for making end-products and for providing different repair tasks and related services.

The roadmapping process was realised in two phases: the first phase was thematic interviews and the second phase was roadmapping. The roadmapping phase was completed in two workshops. In both workshops, the participants were divided into four thematic groups: (1) measuring and enhancing productivity, (2) innovative service concepts, (3) learning and education, and (4) internationality. Each of the groups made their own thematic roadmaps. The aim of the roadmapping process was first to form a vision to which the participants could commit, and to build roadmaps accentuating the following emphases: enhancing the added value for the end-user; developing

Table 4. Summary of the knowledge spaces of the SSB network.

Knowledge space	Description	Key systemic capacities associated with the space	Forms of project knowledge
Strategy	Exercise defined the emerging field of service research and its future possibilities Explicit focus on establishing a 'service mind-set' in the organisation	Capacities for use of the existing service knowledge Capacities for structured openness, especially in creation of new service knowledge internally at VTT To fortify VTT's brand as a service research organisation by stating the VTT state-of-the-art and vision for the future	Knowledge generated via roadmapping was iteratively used throughout the strategy building process, e.g. definition of service, identification of most important research needs, generation of project proposals
Social/actor	Identification of most important players in the field of service research internally and externally Markets for new services and service providers in the field	Capacities and methods for linking and sharing existing knowledge internally, across disciplines and organisational functions Capacities and methods for creating new knowledge in the network Endorsed a view of VTT as a key player in service research both in Finland and Europe	VTT's vision of service was built on the basis of past development paths, current service trends, opportunities and challenges Identified VTT's own capacities, and potential development paths Identified societal and market drivers

new visionary services; and securing the continuation of the developmental activities in the field. The temporal span of the roadmap was about 10 years, until the 2020s.

Knowledge spaces and systemic capacities

The construction machinery roadmap can be approached as systemic I type roadmapping process, which aimed to contribute to the strategic and visionary spaces, and to come up with related business decisions. The knowledge spaces of the project are summarised in Table 5.

In the *strategy space*, the construction roadmap emphasised three aspects. The first aspect was about building new client-oriented and environmentally sustainable practices in the field, for example, through the application of life cycle analysis. The second aspect was to open the field towards more efficient use of ICTs in the processes, such as solutions for distance-based monitoring, the use of building information models, and different kinds of digital systems to help optimisation and customer selection. The third aspect was the need to move away from the intense price competition towards integrated service packages that would be based on quality-oriented pricing schemes. It was assessed that, to reach these aims, the construction machinery field should partake in the processes of the clients in new ways and seek long-lasting partnerships.

In the *visionary space*, the key ideas accentuated the need to build a new kind of service-oriented operation culture in a field that is considered quite conservative by the actors. This culture should focus, obviously, not only on the clients, but also on the potential future employees in the field. Visionary ideas about technology-enabled services could also be one way to stimulate

Table 5. Summary of the knowledge spaces in the Construction Machinery Roadmap.

Knowledge space	Description	Key systemic capacities associated with the space	Forms of project knowledge
Strategy	Building client-oriented and environmentally sustainable practices in the field Opening the field towards the efficient use of ICTs From intense price competition towards integrated service packages	Capacities to understand and take part in the processes of the clients Fostering abilities to build long-lasting partnerships with the clients	Building thematic roadmaps on four project themes: (1) measuring and enhancing productivity, (2) innovative service concepts, (3) learning and education, and (4) internationality Using prospective argumentation to endorse the strategic aims
Visionary	Forming a new kind of service-oriented culture in a rather conservative field Forming visionary ideas about the systemic and technology-enabled services in the field	Fostering structural adaptability for the adoption of new kinds of practices Constructing a horizontal anticipatory agency, especially through novel technology and services concepts Endorsing education and international influences in the field	Building explicit visions in roadmap themes: (1) measuring and enhancing productivity, (2) innovative service concepts, (3) learning and education, and (4) internationality Making visionary timelines for the adoption of new solutions Envisioning development projects based on the results

this aspired culture. Examples of these new service concepts are, for example, different kinds of circumstance services, such as building in stable and dry conditions, or controlling the amount of dust formed in the processes. Another example is the notion of comprehensive equipment management, which would transparently integrate planning, logistics, and information about the location of the machinery. In order to achieve these aims, a structural openness for the adoption of new practices should be fostered. In addition, the field of construction machinery should actively endorse a kind of horizontal anticipatory agency, for example, through novel technology and services concepts, and should underline the importance of continuous education.

Nordic ICT Foresight: strategy space and visionary space, systemic II scope

Our fourth case is Nordic ICT Foresight, an example of a systemic foresight exercise (Ahlqvist et al. 2007a, 2007b). It focussed on building a policy-level perspective for Nordic-level development. The systemic policy orientation distinguishes Nordic ICT Foresight from the three previous examples. The systemic orientation was visible in the 'Russian doll' style of layered project structure: the project operated simultaneously on the layer of separate ICT applications, on the layer of ICT adoption in four fields (the experience economy, health care, the production economy, and information security), on the layer of four Nordic countries (Finland, Sweden, Norway, and Denmark) and on the layer of the Nordic region as a strategic entirety.

The process was realised in 2005–2007 between VTT Technical Research Centre of Finland, FOI (Sweden), SINTEF (Norway), and DTI (Denmark). There were five research phases

(Figure 6). In the first phase, which was the desktop survey, the boundaries of the technological field were defined. The second phase, the SWOT analysis, identified trends in the national ICT business and research environment in the four Nordic countries. The third research phase, the scenario and vision workshop, had two purposes: to create four external scenarios and to produce a set of socio-technical ICT application visions. The fourth phase, the roadmapping workshop, created roadmaps on selected socio-technical visions. In the final research phase, the action workshop, a set of actions to be taken by the key players in the Nordic countries was depicted.

Knowledge spaces and systemic capacities

Nordic ICT Foresight can be perceived as a systemic II type of policy-oriented foresight process, which aimed to contribute to the strategy space and the visionary space. The project completed a systemic scenario exercise that integrated visionary components, for example, in the form of application visions and exploratory socio-technical roadmaps. The knowledge spaces of the project are summarised in Table 6.

Nordic ICT Foresight operated primarily in the *strategy space*. It aimed to assess and compare the implications of the ICT applications in four Nordic countries (Denmark, Finland, Norway, and Sweden). It aspired to understand what the notion of 'Nordicness' would signify in the context of ICT applications. From a capacity perspective, the project aimed to construct a basis for understanding the Nordic region as a 'common strategy region' in the ICT context. It also attempted

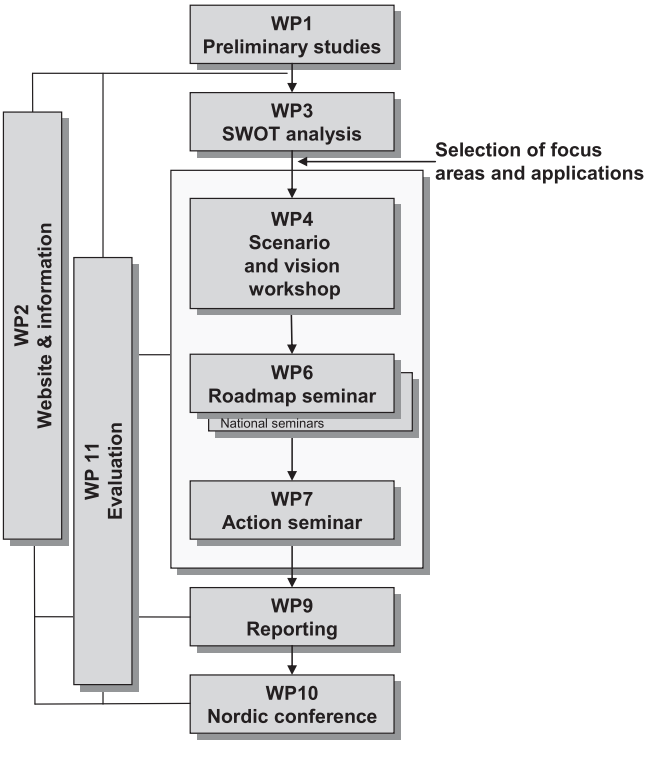

Figure 6. Nordic ICT Foresight process (Ahlqvist et al. 2007a, 15).

Table 6. Summary of the knowledge spaces in the Nordic ICT Foresight.

Knowledge space	Description	Key systemic capacities associated with the space	Forms of project knowledge
Strategy	Assessing the implications of the ICT applications in four Nordic countries (Denmark, Finland, Norway, and Sweden) Evaluating the value and meaning of the 'Nordicness' in the context of ICT applications Creation of four context scenarios on the adoption of ICT in four Nordic countries	Constructing a basis for understanding Nordic region as a 'common strategy region' in the ICT context Building structural openness for a Nordic region in the context of ICT adoption Building system-level strategic abilities at Nordic regional level	Forming a perspective of ICT convergence in the Nordic region (fragmented–modularisation–ubiquitous) Building a systematic set of actions in the medium and long term and in the context of the four scenarios Construction of implementation strategies
Visionary	Building long-term visionary glimpses to the futures of ICT applications and adoption of ICT in Nordic region Assessing the explorative application visions in the context of four scenarios Creation of scenario-based visionary socio-technical roadmaps on several application visions	Aimed at systemic openness towards future development options in the ICT context Built capacity for systemic resilience at Nordic regional level	Systematic assessment of the different future options: plausible, disruptive, alternative, unlikely Identification of 'black swan' type of development options Construction of visionary adaptive strategies on the basis of assessment of alternatives

to build structural openness for the Nordic region in the adoption of ICTs, and fostered system-level strategic abilities at the level of the Nordic region. In addition, the project built a systematic set of actions in the medium and long term, and constructed explicit implementation strategies.

The project also functioned in the *visionary space*. It built long-term visionary glimpses of the adoption of ICT applications on the scale of the Nordic region. It provided an assessment of explorative visions in the context of four scenarios and created scenario-based visionary socio-technical roadmaps. In the capacity view, the project endorsed systemic openness towards future development options in the context of ICT, and built adaptive systemic capacities that would induce resilience. The visionary space was opened by systematic assessment of different future options, for example, by evaluating the plausible, disruptive, alternative, unlikely, and even 'black swan' type of developments in the context of the scenarios. On this basis, the project fostered so-called adaptive strategies, that is, identification disruptive strategic 'holes' for Nordic ICT development.

Case conclusions and lessons learned

All the case examples emphasise the roles of partial structural openness and an anticipatory agency in the whirl of changes that RTOs, industries, and national innovation systems face. In the cases, the targets of the systemic capacities varied according to the different knowledge spaces and roadmap scopes, from a readiness to adopt new technological solutions, to the construction of novel knowledge linkages in an organisation, and even towards fostering a visionary innovation

culture at the level of nation-states. Three of the cases (building services roadmap, SSB network, and construction machinery roadmap) emphasised the building of a novel service-oriented culture, albeit through differing knowledge spaces and roadmap scopes. The fourth case, Nordic ICT Foresight, was a policy-oriented exercise targeted at national and transnational (Nordic) scales.

Two of the projects, the building services roadmap and the construction machinery roadmap, were explicitly about renewing an already well-established industry with locked-in practices. The building services roadmap was about renewing the research emphases at VTT, and the construction machinery roadmap was about finding new business directions in the network of actors in the field. The key systemic capacities in these cases emphasised especially the structural openness towards new technological impulses and towards a novel 'service mind-set'. The anticipatory agency related to the readiness to adopt new solutions, and fostering a service-oriented perspective was of importance in the cases. The case of the SSB network, which was about building an explicit service-oriented R&D trajectory in an engineering-oriented RTO, aimed to empower actors and, through this, to establish and strengthen VTT's organisational identity as a novel 'player' in service science. Thus, it fostered the formation of an anticipatory culture, through empowering an anticipatory agency among the in-house professionals. The Nordic ICT Foresight aimed to foster the visionary notions of 'Nordic innovation culture' and 'common strategy region' in the context of ICT applications. From the perspective of systemic capacities, the construction of an integrative 'Nordic' anticipatory culture was a critical theme.

It can be assessed that in all the cases, the actual roadmapping process was able to endorse new ideas about markets, services, and solutions in the topic areas. The roadmapping process was also able to foster a shared understanding of the critical future gaps, and the necessary systemic capacities to tackle these gaps. However, it should also be acknowledged that three of the exercises, excluding the continuous development process of the SSB network, were somewhat singular foresight projects. This means that, even though they are inherent parts of the 'knowledge continuum' at VTT, there have not been strong systematic efforts to combine the results into an evolving structure of anticipatory knowledge, which would be the optimal scenario in constructing systemic transformation capacities. Thus, applying the project knowledge in changing organisational practices would still require further activation rounds.

There are also factors that hinder the use of future knowledge. One hindrance to converting the ideas into practices could be the somewhat abstract nature of the case examples: all the cases dealt with topics that are likely to spur different interpretations among the actors and stakeholders. Therefore, a kind of interpretative phase after the visionary phase could be useful in putting the ideas into practice. In addition, a general problem with these kinds of exercises is that, even though the produced knowledge could be highly relevant, much of the useful future knowledge is left inside the project reports without further systematic steps.

Concluding remarks

The article discussed the construction of the systemic transformation capacities in an RTO. It proposed that two kinds of systemic capacities are of importance: (1) partial structural openness and (2) a horizontal anticipatory culture based on an anticipatory agency. We presented a model of a process-based roadmap with four knowledge spaces, which extends the horizons of roadmapping. We also presented four case examples – the Building Service Roadmap, SSB Network, Construction Machinery Roadmap, and Nordic ICT Foresight – which all represented different roadmap scopes and knowledge spaces.

The article created insights for managing systemic entities, such as organisations or companies, in systemic environments. The first insight is to start with the fundamentals, such as defining the organisation's core purpose, framed in a systemic-temporal paradox. The second insight is to endorse structural openness. This means to define a space of possibilities unfurled in the context of the core purpose. The key is to find the core competencies of the organisation and induce adaptability by seeking the most critical combinations of these competencies. The third insight is about an anticipatory culture. The fundamentals and competencies need to be positioned in the context of 'mobile strategies' that enable the continuous elaboration of targets and the planning of actions.

As discussed in the article, process-based roadmapping is one potential avenue for the construction of such mobile strategies. On the basis of the cases, it can be assessed that roadmapping is most applicable to processes aimed either at the technology space, the social/actor space, or the strategy space. In the case of the visionary space, methods that bring more creative latitude, such as constructing exploratory future narratives or making experimental mini-scenarios, could be handier than more structured roadmapping. In addition, exploratory approaches based on, for example, modelling, simulation, or weak signal analysis could be useful in charting the visionary space.

The results provide strategic directions for companies and organisations when responding to system-level changes. First, activation of the systemic transformation capacities is useful when responding to the so-called 'grand challenges', such as climate change or global resource scarcity. For companies and organisations alike, tackling these kinds of complex challenges, either from the perspective of business or governance, requires integration of competencies over the traditional sectoral boundaries. Second, the public organisations are increasingly facing societal demands to move towards more transitional mission-oriented governance regimes, where the policy fields are integrated in new ways and steered against continuously fulminating, multi-faceted future targets. Fostering structural openness and an anticipatory agency, as discussed, would be especially beneficial in tackling these kinds of systemic challenges. In general, it could be stated that RTOs, companies, and other organisations would benefit from thinking explicitly in all of the four knowledge spaces discussed in the article.

Finally, at least three paths for future research can be delineated. First, the notion of systemic transformation capacities should be analysed from perspectives other than roadmapping. The lessons of the article could be ennobled by putting them in a dialogue with other foresight methods, such as scenario and weak signal analysis. Second, systemic transformation capacities could also be catalysed by integrating novel ICT-based analysis tools. For example, simulation, modelling, technology mining, or cognitive mapping could provide useful data for the identification of potential 'boundary' competencies. Third, research should pay more attention to the systemic and temporal relativity of the organisations, that is, to how the interplay of past, present, and future affects the organisational practices. Forward-looking sensibility is ineluctably related to contextual historical understanding, and vice versa. Thus, foresight exercises would benefit from the increased historical depth, and historical analyses would benefit from the deeper engagement with how the contextual future perspectives are manifested in the 'past presents'.

Note

1. In this article, it is not possible to provide a review of the origins and different dimensions of roadmapping. For useful reviews, see e.g. Barker and Smith (1995), Kostoff and Schaller (2001), Farrukh, Phaal, and Probert (2003), Kostoff, Boylan, and Simons (2004); Phaal, Farrukh, and Probert (2004), Lee and Park (2005) and Phaal and Muller (2009).

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References

Aaltonen, M. 2007. Chronotope space: Managing the complex trade-offs between the properties of the strategic landscape and the time frame being considered. *Foresight* 9, no. 4: 58–62.

Ahlqvist, T. 2009. *Roadmaps and policy-making*. Lecture at the roadmapping course for DIIRD (Department of Industry, Innovation and Regional Development), Victoria, Australia. September 15 in Phillip Island, Victoria, Australia.

Ahlqvist, T., A. Bäck, S. Heinonen, and M. Halonen. 2010. Road-mapping the societal transformation potential of social media. *Foresight* 12, no. 5: 3–26.

Ahlqvist, T., H. Carlsen, J. Iversen, and E. Kristiansen. 2007a. *Nordic ICT Foresight. Futures of the ICT environment and applications on the Nordic level*. Helsinki: VTT Publications, Edita Prima Oy.

Ahlqvist, T., H. Carlsen, J. Iversen, and E. Kristiansen. 2007b. *Nordic ICT Foresight. Futures of the ICT environment and applications on the Nordic level*. Summary report. Publication of Nordic Innovation Centre.

Ahlqvist, T., V. Valovirta, and T. Loikkanen. 2012. Innovation policy roadmapping as a systemic instrument for forward-looking policy design. *Science and Public Policy* 39, no. 2: 178–90.

Ahola, J., T. Ahlqvist, M. Ermes, J. Myllyoja, and J. Savola. 2010. *ICT for environmental sustainability. Green ICT roadmap*. VTT Research Notes 2532.

Arnold, E., J. Clark, and Z. Jávorka. 2010. *Impacts of European RTOs. A study of social and economic impacts of research and technology organisations*. A report to EARTO. Technopolis Group Ltd.

Barker, D., and D.J.H. Smith. 1995. Technology foresight using roadmaps. *Long Range Planning* 28, no. 2: 21–8.

Blackwell, A.F., R. Phaal, M. Eppler, and N. Crilly. 2008. Strategy roadmaps: New forms, new practices. In *Diagrams 2008*, ed. G. Stapleton, J. Howse and J. Lee, 127–40. Berlin: Springer-Verlag.

Engeström, Y. 2001. Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of Education and Work* 14, no. 1: 133–56.

Farrukh, C., R.D. Phaal, and R. Probert. 2003. Technology road mapping: Linking technology resources into business planning. *International Journal of Technology Management* 26, no. 1: 12–9.

Geels, F.W. 2004. From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy* 33, nos. 6–7: 897–920.

Halonen, M., K. Kallio, and E. Saari. 2010. Towards co-creation of service research projects: A method for learning in networks. *International Journal of Quality and Service Sciences* 2, no. 1: 128–45.

Heracleous, L., and C.D. Jacobs. 2008. Crafting strategy: The role of embodied metaphors. *Long Range Planning* 41, no. 3: 309–25.

Kostoff, R.N., R. Boylan, and G.R. Simons. 2004. Disruptive technology roadmaps. *Technological Forecasting & Social Change* 71, no. 2: 141–59.

Kostoff, R.N., and R.R. Schaller. 2001. Science and technology roadmaps. *IEEE Transactions on Engineering Management* 48, nos. 1–2: 132–43.

Könnölä, T., T. Ahlqvist, A. Eerola, S. Kivisaari, and R. Koivisto. 2009. Management of foresight portfolio: Analysis of modular foresight projects at contract research organization. *Technological Analysis & Strategic Management* 21, no 3: 381–405.

Lee, S., and Y. Park. 2005. Customization of technology roadmaps according to roadmapping purposes: Overall process and detailed modules. *Technological Forecasting & Social Change* 72, no. 5: 567–83.

Myllyoja, J., N. Wessberg, and P. Pajakkala. 2012. *Rakennuskonetoimialan visio ja tulevaisuustiekartta 2012–2020*. [A vision of the construction machinery sector and future roadmap 2012–2020]. VTT Asiakasraportti VTT-CR-00459-12. VTT, Tampere [In Finnish].

Paiho, S., T. Ahlqvist, E. Lehtinen, J. Laarni, K. Sipilä, P. Ala-Siuru, and T. Parkkila. 2007. *Talotekniikan kehityslinjat. Teknologiat ja markkinat* [Development trajectories of the building services. Technologies and markets]. VTT Tiedotteita 2379. Edita, Helsinki [In Finnish].

Petrick, I.J., and A.E. Echols. 2004. Technology roadmapping in review: A tool for making sustainable new product development decisions. *Technological Forecasting & Social Change* 71, no. 1–2: 81–100.

Phaal, R., C. Farrukh, and D. Probert. 2001. *Technology roadmapping: Linking technology resources to business objectives*. Cambridge: University of Cambridge. http://www.ifm.eng.cam.ac.uk/ctm/publications/tplan/trm_white_paper.pdf (accessed August 18, 2009).

Phaal, R., C.J.P. Farrukh, and D.R. Probert. 2004. Technology roadmapping – a planning framework for evolution and revolution. *Technological Forecasting & Social Change* 71: 5–26.

Phaal, R., C.J.P. Farrukh, and D.R. Probert. 2006. Technology management tools: Concept, development and application. *Technovation* 26, no. 3: 336–44.

Phaal, R., and G. Muller. 2009. An architectural framework for road-mapping: Towards visual strategy. *Technological Forecasting & Social Change* 76: 39–49.

Smits, R., and S. Kuhlmann. 2004. The rise of systemic instruments in innovation policy. *International Journal of Foresight and Innovation Policy* 1, nos. 1/2: 4–32.

Whittington, R., and Cailluet, L. 2008. The crafts of strategy. *Long Range Planning* 41, no. 3: 241–47.