# Science and Technology Roadmapping for Policy Intelligence

# Lessons for Future Projects

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## Abstract

The term "Technology Roadmapping" (TRM) refers to a range of forecasting or foresight studies including visions and detailed projections of future possible technological developments, products or environments. TRM methodologies have been developed within high-tech companies and subsequently extended to consortia of companies and even to entire industrial sectors [Da Costa *et al.* 2003].

More recently, a number of research institutes and think-tanks have made significant efforts to adapt this methodology to the provision of intelligence to support the policy-making process. In the context of rapid scientific and technological developments, it can contribute by providing the strategic intelligence needed to optimize public R&D investments and ensure their relevance to society [Da Costa *et al.* 2003].

The aim of this paper is to reflect on the practises of science and technology roadmapping for policy intelligence, building on lessons generated by the "Science and Technology Roadmapping Project" conducted by the IPTS[1] and members of the ESTO[2] network during 2002 and 2003.

The IPTS/ESTO project aimed at assessing the potential of roadmapping methodologies to respond to the needs of policy-making. In addition to an overarching study to review the state of the art and develop a reliable and replicable methodology, it comprised two pilot roadmaps, centred on the development and application of science and technology to meet key socio-economic challenges:

- The "Ambient Intelligence in Everyday Life" Roadmap;
- "The Healthcare Technologies Roadmap: Effective Delivery of Healthcare in the Context of an Ageing Society,"

Based on the results of the study, this paper will set out the main lessons and conclusions arising from the project, particularly in terms of:

- the refinement of the methodology;

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[1] Institute for Prospective Technological Studies) of the European Commission's Joint Research Centre.

[2] European Science and Technology Observatory network.

- the management of the process of roadmapping, including preparation, implementation, and the validation and diffusion of results;
- specifications for future roadmapping projects; and
- implications for other kinds of forecasting and foresight activities.

# 1. Introduction

## 1.1. The Origin: TRM in Corporate and Industries

The terms “roadmap” and “roadmapping” are applied to a broad range of activities.

> *A literature survey revealed that the single word "roadmap" has surfaced as a popular metaphor for planning S&T resources. The variant "roadmapping" is a new verb that describes the process of roadmap development.*
>
> Kostoff [2002]

“Technology Roadmapping” (TRM) usually refers to various types of forecast or foresight studies including visions and/or detailed projections of future possible technological developments, products or environments [Da Costa *et al.* 2003]. Since the mid-1980s, TRM has been developing within R&D and strategic planning teams in high-tech companies [Willyard McClees 1987]. In this context, graphic representations of the future for one or a family of products are developed, which integrate relevant strategic information such as technologies, products, markets. TRM aims at supporting the development of new products by developing causal or temporal relations between the technological possibilities and choices and the business objectives thereby highlighting the necessary steps to reach the market with the right products at the right time [Groenveld 1997].

> *A roadmap is an extended look at the future for a chosen field of enquiry composed from the collective knowledge and imagination of the brightest drivers of change in that field.*
>
> *Roadmaps communicate visions, attract resources from business and government, stimulate investigations and monitor progress. They become the inventory of possibilities for a particular field…*
>
> *Robert GALVIN, Chairman and CEO of Motorola*, [1998]

As the concept and methodologies of TRM have been maturing its design and application have been extended and developed from single companies to consortia of companies and even entire industrial sectors [Da Costa *et al.* 2003]. An entire industry can become more competitive in the long term by sharing R&D investments and results in the pre-competitive domain, thereby creating common technology standards and platforms, sharing risks and avoiding duplication of efforts. Each partner is thus able to identify and develop the technologies needed to succeed in the highly competitive global market.

Industry TRM is used as an information and strategic planning tool and is also oriented towards action. It is about developing, organizing and presenting information on the critical technological milestones to be completed within certain time frames by those players aiming for key roles. It aims at providing the information needed to compare different technology alternatives.

In addition to the technological developments, some industry TRMs embrace organizational and human resource issues. Also, for some companies, interest in industry TRM could lie outside their core concern, i.e. in monitoring competing, synergistic or alternative technologies in a way they would not be able to using only internal resources.

The classic example of Industry TRM is the International Technology Roadmap for Semiconductors’ [ITRS 2004], first published in 1999, which originated from the US-based ‘National Technology Roadmap for Semiconductors’ (NTRS). It is a cooperative effort of the global industry manufacturers and suppliers, government organizations, consortia, and universities from virtually every country active in this field to ensure advancements in the performance of integrated circuits by identifying the technological challenges and needs facing the semiconductor industry over the next 15 years. It has become the world-wide reference document for the semiconductor industry.

TRM is also used in the forecasting and development of "trans-disciplinary hi-tech goals" entailing collaboration between various partners. These goals may be objects or environments (e.g. the connected home or vehicle, etc.), functional objectives (e.g. reducing manufacturing defects, hazards to workers and environment, time and cost of manufacturing [U.S. Department of Energy 1998] or competitive objectives.

### 1.2. S&TRM for Policy Intelligence

Science and technology (S&T) are advancing at an increasingly rapid pace while having complex forms of interaction with the economy, society and the environment. Effects are often not immediate but take place after a substantial delay or through second or third order effects. The understanding of the risks and opportunities of technological developments is essential for the policy-making process, not only in Research and Development but for virtually all the other fields of policies (economy, health, defence, education, culture...).

In our "information society", data and reports on a broad range of subjects are plentiful but the translation into knowledge and appropriation by the decision-makers is challenging: policy-makers and corporate executives do not have enough time to read, understand and synthesise this material on complex S&T developments and their impacts. However, they cannot afford to wait until all the impacts, risks, and opportunities have been clarified before they come to decisions. Actions in the earliest phases of technological developments are the most effective whereas this is the time when one knows less about them.

Since the mid-1990s, various research institutes and think-tanks have worked to adapt the TRM methodology to the provision of intelligence for policy-making in areas where S&T play a prominent role [Cahill & Scapolo, 1999] [Da Costa *et al.* 2003]. Its objective is to provide the strategic intelligence needed by policy-makers to optimize public R&D investments and ensure their relevance to society.

This paper is concerned with this last case. The expression "S&TRM for Policy Intelligence" was developed to illustrate that:

- As its scope is larger, it might have to move further upstream beyond technological developments into scientific research, in order to envisage the potential future applications and,
- Its objective is to provide the strategic intelligence required by the policy-makers to optimize public R&D investments and ensure their relevance to society.

The potential of S&TRM is significant in this context. It can be an important input in the selection of research priorities by highlighting the emerging S&T themes likely to impact on policy in the coming years. In a recent benchmarking study, roadmapping was highlighted as one of the "recommended best practices" for the selection of priorities in R&D programmes since it does not only identify the bottlenecks that need to be addressed within a realistic time frame, but it can lead to a high degree of consensus when the potential beneficiaries are involved in the agenda-setting process [Friedewald *et al.* 2005].

Finally, it can be said that the practises of TRM are diverse and that this methodology has yet to reach maturity. "*It is still developing from an art into a discipline, from exploring a spectrum of methodologies for different goals and situations into systematically applying basic principles and methods*" [Eggermont 2003].

## 1.3. The IPTS/ ESTO Roadmapping Project

The IPTS[3] / ESTO[4] Science and Technology Roadmapping (S&TRM) ran from September 2002 until May 2003. Taking major socio-economic challenges facing Europe as starting points, it intended to address two questions:

1. What are the emerging technologies able to contribute to the responses to these challenges?
2. What are the pathways between these challenges and responses?

The pilot phase of the project comprised an overall study to review existing studies and approaches and to develop the methodology for mapping science and technology and the production of two pilot roadmaps:

- The "Ambient Intelligence in Everyday Life" Roadmap [Friedewald & Da Costa 2003];
- "The Healthcare Technologies Roadmap: Effective Delivery of Healthcare in the Context of an Ageing Society," [Braun *et al* 2003].

As explained above, TRM originated from industry. The aim of this project was therefore to assess the value of this methodology for policy intelligence, whether challenge-centred roadmaps could be a valuable and cost-effective tool to inform research and development policy at European level and to support the needs of a range of users including policy-makers.

TRM traditionally focuses on technological developments, applications and products. The intention was to assess whether it could also be adapted to evaluate fundamental research for which there is as no application yet and whether it was possible to encompass the economic, political and social dimensions, and the complex interactions between them.

The duration of each of the two pilot roadmaps was six months, and they were developed as two separate projects. As detailed within the following sections, the scope of each of them was defined by a far-reaching socio-economic 'challenge' rather than a technological sector *per se*.

Six institutes from the ESTO network participated in each project. At least three workshops were organised for each one. The first (challenge-definition workshop) and the last (validation workshop) included external experts.

During the challenge-definition workshop, a group of experts was convene to define, in consultation with the project partners and relevant European Commission services, the parameters of the main challenges and to identify emerging technological solutions, in relation with the main socio-economic factors.

Once identified, detailed examination of the development of key technologies was conducted by the project partners. They assessed the state of the art of the technologies, their likely trajectories of development, their economic and commercial potential, their socio-economic impacts, and the identification of the relevant scientific and technological actors and other stakeholders.

At the end of each pilot roadmap, a validation workshop including invited experts and European Commission officials were organised to review the consistency of the output particularly with respect to the goals set at the beginning of the project. To a large extent the material of this paper derives from these workshops.

## 1.4. Ambient Intelligence in Everyday Life (AmI@Life) Roadmap

The vision of Ambient Intelligence (AmI) [Ducatel *et al* 2001] [ISTAG 2002] [Aarts & Marzano 2003] envisages the future of Information and Communication Technologies (ICT). According to this vision, human beings will be at the centre and technologies will be designed for people rather than requiring people to adapt to them. The emphasis will be put on user-friendliness, efficient and distributed services support, user-empowerment, and support for human interactions. People will be surrounded

[3] Institute for Prospective Technological Studies) of the European Commission's Joint Research Centre.

[4] European Science and Technology Observatory network.

by intelligent intuitive interfaces embedded in all kinds of objects and environments and capable of recognizing and responding to the individual needs in a seamless, unobtrusive and often invisible way.

The pilot roadmap addressed the potential of full ICT integration in our everyday life. The 'challenge' was the universal and trusted access to Ambient Intelligence in Everyday Life, how these technologies and the functions based on them could actually contribute to an improvement of the everyday life of ordinary people. Besides technological forecasting, key socio-economic and cultural factors were taken into account.

### 1.5. Healthcare Technologies Roadmap (HCTRM)

The Healthcare Technologies Roadmap (HCTRM) aimed at providing an overview of the major technological and socio-economic trends in healthcare technologies. The challenge was the effective delivery of quality healthcare in the context of an ageing population, and of the enlargement of the European Union.

## 2. Main Characteristics of S&TRM

Two key interrelated functions have emerged as central to the TRM or S&TRM methodology:

- TRM usually includes graphic representations in which "nodes" (past, present or future states of the art in S&T development) are connected by "links" (causal or temporal relations) showing the nature, rate and direction of potential S&T developments from or towards those nodes. As such TRM is a technology forecasting and foresight methodology.
- These representations can be put to practical use, in illuminating the way forward and in informing decisions about possible future options. As such, a roadmap is also a planning methodology, "*a traveller's tool that provides essential understanding, proximity, direction, and some degree of certainty in travel planning.*" [Kostoff & Schaller 2001]

Its main characteristic, in comparison with other forecasting or foresight methods, is that it includes graphic representations, such as scenarios include stories. These are an effective way to demonstrate actual and possible causal and temporal relations between successive or parallel steps or "nodes" and thus to provide assistance to policy makers under information overload and time pressure to grasp effectively the most important elements and relations within a complex systems including scientific and technological, economic, political and social dimensions. Some inconsistencies, such as those between estimations from different sources or those arising from technological co-dependencies, can be put resolved through the construction of respectively the "nodes" or the "links" of the roadmaps.

As in case of other foresight methods, TRM is valuable both as a process and as a product. As a process, roadmapping brings together experts from different backgrounds to share knowledge and to build common perspectives and visions. As a product, roadmapping provides information and guidance to an audience beyond the original participants and stakeholders.

The main characteristics of successful roadmaps are their clarity with the focus put on the information displayed in the graphics, their synthetic view and their relevance to allow decision-makers to concentrate on what is strategic for the decisions to be taken rather than being diverted by excessive detail.

S&TRM for policy intelligence can, in theory, be constructed through and across broad S&T fields, extended upstream to fundamental research and observed through a challenge-centred perspective. One of the main difficulties is thus to ensure the coherence and a homogeneous depth of analysis across broad areas, which are needed if this methodology aims at assisting policy-makers in comparing the appropriateness, efficacy and efficiency of public investments in different fields.

# 3. Preparatory Phase

Arguably, the main lesson learnt during this project is that the success depends primarily on a well-designed and carefully-conducted preparation phase. A roadmap does not stand on its own but takes most of its value from its ability to respond to the explicit or implicit needs of the clients. This could also be said about most of the foresight or policy-support studies.

## 3.1. Requirements for Starting the Project

### 3.1.1. Full Commitment of Clients

The clients of the project have to be formally and unambiguously committed for the whole project. Regular interactions between the project team and the clients have to be maintained throughout the process, whose modalities of interactions have to be formalized. Frequent references to the specifications of their requirements and needs have to be made but at the same time feedback procedures should be designed to realign the objectives and the process during the course of the project, if needed.

### 3.1.2. Composition of the Team

The **core team** is in charge of defining the references, writing domain papers, creating a structure for the roadmap and filling it using input from experts and/or on-desk studies.

The **coordinator** or **facilitator** can be a member of the core team or an external consultant and is responsible for keeping momentum in the process. The coordinator is not necessarily an expert of the field, but an “informed and interested generalist” with the capacity to listen, to think strategically and to synthesise information and ideas. The real added value of this facilitator is to manage groups and to produce the strategy from their interactions [de Laat 2004].

The team should be closely coordinated and if the roadmap is developed through a **consortium** of external partners it will more efficient to work with a relatively small consortium (2-4 partners depending on the budget).

### 3.1.3. External Participants

A good network of experts and external reviewers is also necessary for providing the most up to date material on technological developments. Depending on the size of the project, the number can vary from a few tens up to more than one hundred. The coordination of a large network is time-consuming and therefore expensive. The level of commitment expected, in terms of the amount of time and effort, has to be assessed from the start, so that the participants know what is expected of them. This requires careful planning. It is not uncommon to underestimate the amount of effort involved, but the enthusiasm of participants may compensate (although this should not be taken for granted).

It might be considered to invite the “leading lights” in the field so as to give credibility and input vision to the output. However, they will need to be convinced of the value of the undertaking. One has to be aware that key actors will only give one chance to an activity (at the most…). If they are not convinced of the value of the project at the first workshop / interview they will not come a second time.

### 3.1.4. Time and Resources

The number of meetings should be appropriate to the breath of the project.

If the project is undertaken through a consortium, enough time should be allocated for team building, for the construction of common references and for the emergence of working modes through collective process rather than only pushed from the coordinator. Meeting with the core team should alternate with workshops involving external experts. The complexity and the breadth of the project should not be underestimated which could lead to a lack of resources for the in-depth study of major issues.

As orders of magnitude, 9 months with a total of 6 meetings, 3 with the core team only and 3 with external experts, is probably a minimum for a policy-intelligence S&TRM.

#### 3.1.5. Knowledge and Expertise

The policy-intelligence roadmap should capitalize on in-house knowledge and expertise. The existing material should be listed and whenever possible reused to avoid duplication. Experience and feedback from previous exercise have to be codified. Co-workers or network members having a content or methodology expertise should be involved, such as through interviews, if they are not directly part of the process.

### 3.2. Assessment of the Needs

In the case of corporate roadmapping, the goals are relatively easily-defined [Da Costa *et al.* 2003]. They are about optimizing R&D decisions and strategic planning for development of new products or more generally delivering the right products on the right market at the right time.

In comparison R&D policy-making could appear complex and fuzzy, with sometimes antagonistic and intertwined goals, some of them explicit and other implicit. Typically policy makers do not come forward spontaneously with requests for specific studies. Usually, only short-term urgent needs are articulated and it may then be too late to undertake elaborate foresight studies. Therefore, the research institutes and think-tanks have to be proactive, identify major socio-economic challenges and propose studies to potential clients. A clear 'market strategy' integrating the roadmapping project within the wider policy context should be established. This is what makes the definition phase so important and structuring for the whole project.

Adhoc interviews and questionnaires have to be designed to record the needs and the wishes. They should be relatively formal and structured in order to build detailed and solid specifications on the three main decisions to be taken: identification of the roadmapping objectives, choice of the roadmapping areas and of the granularity, approach to the future, however sufficiently open not to restrain too much creativity. The feasibility of meeting client requirements needs to be viewed in the context of available resources.

#### 3.2.1. Objectives

The assessment has to be based on open questions such as: "What kind of questions do you have?", "What would you need a roadmap for?", "How would you like to use it?" Detailing the need for something abstract which has not been developed yet and which can take different meanings is challenging. Experience shows that an analysis of the needs at a "high" level (the fundamental reasons for undertaking the project) should precede detailed specifications. The interactions between the clients and the service providers involve a lot of tacit knowledge and an in-depth experience and understanding of the operation of the organisation.

#### 3.2.2. Focus and Scope

Precise definition of the focus and scope of the roadmap is essential but challenging.

As presented above the traditional TRM methodology implemented in corporate and industries is technology-centred. However, in the frame of policy intelligence, it is wise to define to define the scope with regard to socio-economic challenges so as to avoid the "solutions looking for a problem" approach.

Schematically, two cases could be distinguished.

In the first case the roadmapping project is launched in a well-defined context, the clients having a clearly-defined agenda. In a policy-support role it is then necessary to be in tune with the current debates concerning the research, development and related policies. The roadmapping needs a clear focus, a core challenge which can be refined by subsequently adding a few more sub-issues. Multiple questions at the same level of emphasis are not operational.

In the case of the IPTS / ESTO pilot roadmaps, the focus was in each case a challenge related to the improvement of the quality of life of European citizens:

- AmI@Life: "Universal and trusted access to Ambient Intelligence in Everyday Life";
- HCTRM: "Effective Delivery of Healthcare in the Context of an Ageing Society".

In the second case, the roadmapping might have an exploratory aspect and used to inform the policy agenda itself by highlighting the emerging S&T themes likely to impact on policy in the coming years.

#### 3.2.3. Breadth and Depth

For the available amount of resources, there is a straightforward trade-off between the scope of the roadmap, breadth of the roadmapping and the depth of the analysis (or granularity) which is feasible. The granularity is related directly to the breadth of the area to be roadmapped. The right balance has to be sought between the roadmap for the generalist ('bird's eye view') which has a broad scope but does not go into deep analysis and the roadmap for the expert ('worm's eye view') which is narrower but goes into greater analytical depth.

Thus, it is essential to be realistic in the definition of the breath of the roadmapping and the depth of the analysis. These are to be determined by the mean of a cautious assessment of the clients' needs and the budget and human resources available. The different stakeholders (policy makers, S&T experts, socio-economic researchers and civil society) which are potential users of the roadmap may have different perspectives.

Schematically, 'company' and 'industry' roadmaps are for experts whereas roadmaps for 'policy intelligence' are for generalists [Da Costa *et al* 2003]. However, even if the objectives and the contexts are not the same, policy intelligence roadmaps may be compared with technology roadmaps on similar subjects, developed in companies or industries. It is not possible to compete directly with these roadmaps, which have budgets of orders of magnitude larger. The ITRS roadmap involves hundreds of people active in the semiconductor industry on a quasi-continuous basis.

On the one hand, it may be wiser to avoid broad and loosely-defined subjects such as ambient intelligence, biotechnologies, nanotechnologies…, and to use S&TRM as an exploration tool to anticipate long term needs which are not necessarily yet articulated, to explore emerging, trans-disciplinary or peripheral issues which are not yet receive wide attention. For instance, it may have been more judicious within the "Ambient Intelligence in Everyday Life" roadmap to replace 'Ambient Intelligence' by 'Interfaces' or 'Everyday Life' by 'Home'.

On the other hand, the question remains whether it is possible to address far-reaching policy goals such as "Knowledge Society for All", which have numerous complex dimensions with a roadmap on "Ambient Interfaces for Home Applications". It may be a valuable contribution to the development of a R&D programme, but may not contribute much to the understanding of fundamental socio-economic challenges. This may actually point to the danger of basis policies on a reduced set of forecasting or foresight output.

Also it is important to keep in mind that the graphic displays of the roadmap are delivered with support documents. In this case, the graphic displays are more a synthetic tool, for the generalist view, whereas the documentation addresses the issues more in depth, for the expert view.

The concept of 'zoom-in / zoom-out' roadmap where a 'generalist' roadmap encompasses nested 'expert' roadmap on the most interesting sub-areas is worth to be explored further. The generalist roadmap is developed first and is used to identify the areas where there are some knowledge gaps which can be roadmapped with a smaller granularity at a later stage.

#### 3.2.4. Approach to the Future

The future can be envisaged in different ways in a foresight exercise including a roadmap.

In corporate and industry planning and technology roadmapping, one single desirable state of the future is envisaged and the exercise consists in finding the paths leading from the present to this state.

This approach is labelled 'normative'. Accordingly, the time horizon is relatively short, from 6 months up to 5 years depending on the sector, and the main quality of the output is to be 'scientifically accurate'.

The 'foresight' school of thought is based on the fundamental postulate that the future cannot be predicted and that various alternative futures of a single present state should be considered. Rupture scenarios are considered, cases such as catastrophic events, or major technological breakthroughs. This is the 'exploratory' approach used in scenario building but innovative within the roadmapping methodology. The time horizon can be much longer, up to 20 years in relatively slow-moving sectors such as energy. In this case, long-term hypothetical or visionary developments could appear with the roadmap. In the preparatory phase of a policy intelligence roadmapping, it is important to assess the sensitivity and the needs of the client in this respect. There is a trade-off between the 'scientific validity' and the 'vision' in the output.

Within the "The Healthcare Technologies Roadmap" [Braun *et al* 2003], a 'normative' approach was adopted. The project team examined the current situation (Footprint Matrix) and a future vision (Matrix 2020) across three main technological clusters (information and communication technologies, medical technologies and genetic technologies) in terms of six principal dimensions of healthcare delivery (promotion, prevention, diagnosis, treatment, monitoring and aftercare).

Within the AmI@Life Roadmap [Friedewald & Da Costa 2003], it was intended to implement an exploratory approach. Concretely, ways were sought to represent the different possible scenarios and the degrees of uncertainty within the graphic displays. A simple colour code was designed with 'green' meaning 'fairly certain short-term extrapolations', 'orange' little uncertainty medium-term extrapolations, 'red' 'high-uncertainty foresight' and blue 'vision or science fiction'. Therefore it was possible to include visions such as 'Goal 2050' where a team of football-playing robots beats the human World Cup champions, even if this is closer to science-fiction than foresight. Visions are often created precisely to influence the factual R&D agenda and should therefore not be neglected within policy-intelligence roadmaps [Dierkes *et al* 1996].

However, estimating 'uncertainty' is not straightforward and results in representations where the estimated degree of uncertainty was almost directly related to the time horizon foreseen for the specific development.

Further developments of the methodology would be needed to make roadmapping fully compatible with an exploratory approach.

### 3.2.5. Information Sources

The term 'TRM' or 'S&TRM' implies that the output should include graphic representations of technological developments but say nothing on the way the information should be collected and processed.

In the case of a policy-intelligence S&TRM, it is important to reflect to which extend the roadmap should be based on original information obtained, for instance, from Delphi studies or brainstorming workshops or whether in should be based on on-desk meta-analysis of existing studies. The former has the advantage of originality whereas the later could base the generalist roadmap on a larger basis of knowledge and is less demanding in terms of resources.

Within the IPTS/ESTO roadmapping project, the main sources of information were desk-based meta-analysis of existing studies, mainly for budgetary and time-constraint reasons. Experts were involved in the scoping phase at the beginning and in the validation phase at the end of the project.

The situation is different in the case of large scale industry technology roadmap. They are typically produced by the dominant players in the field who have high personal stakes in future developments and for that reason may tend to ignore some weak signals (Unix OS, Internet infrastructure, novel programming languages, etc) up to the time point were the importance of these technologies became obvious to everyone.

The open issue is how the huge and fast-growing body of scientific material could be mined and searched for relevant for relevant information. Teams of experts would probably cover this body in a far from comprehensive way. Only advanced text and data mining tools could possibly allow a breakthrough.

### 3.3. Kick-Off of the Project

Once detailed specifications for the project have been produced and agreed by the clients, it is necessary to assess the feasibility of the project before taking the final decision to proceed. The decision to continue the project has to be taken at a high level of management after common understanding has been built between the clients, the management, the coordinator, the core team and the main partners.

## 4. Implementation Phase

### 4.1. Construction of the Roadmap

The construction of the roadmap itself consists in collecting, synthesising and validating the information, and representing the trends within graphic displays associated with support documents.

An important lesson is that aiming at building a single, standardized and general methodology is neither practical nor desirable. On the contrary, the approach should be based on a light and modular process using a "methodological toolbox" with different modules depending on the roadmapping areas, issues, context and objectives.

Schematically, the methodology consists in relating major political or socio-economic challenges, seen as potential outputs of R&D developments, back to the present S&T policies through various technological paths. Traditional TRM tends to focus on the development trajectories of technologies to provide new products (Corporate TRM) or on detailed enabling technologies in the pre-competitive domain (Industry TRM).

Within the AmI@Life roadmap a 'function-oriented' approach was implemented in order to give a fuller account of the "innovation chain", also including non-technological factors. It can be seen as an intermediate way between the technology-push and the user-pull approach.

The process consists of the following four successive but interrelated phases (see figure 1):

1. **Preparation of Review Paper** linking the user needs with key functions where AmI is expected to "make a difference", to capture both foreseeable AmI applications and everyday behaviour (social trends).
2. **Definition of Key Technologies** needed for the development of the AmI applications and/or functions and construction of the **Matrix Key Functions versus Key Technologies**.
3. **Mapping of Key Technologies over Time**, using a yearly time scale and a time horizon of up to 15 to 20 years. This is the **Technology Roadmap** synthesising the:
    - Key nodal points;
    - Potential breakthroughs or disruptions;
    - Alternative scenarios;
    - Co-dependencies, i.e. how different technologies need to evolve and come together at a certain point in time in order to allow progress at macro-level.
4. From the two previous steps, the potential trajectories of key functions/ products versus time are derived. This is the **Function Roadmap** synthesising the:
    - Key nodal points, milestones or 'rendez-vous'[5];
    - Potential breakthroughs or disruptions of different natures (S&T, economy, environment, society, demography, policy);
    - Critical paths for the development of the key functions;

[5] Meeting of enabling technologies for the emergence of a new generation of products / services [Eggermont 2003].

* Alternative scenarios;

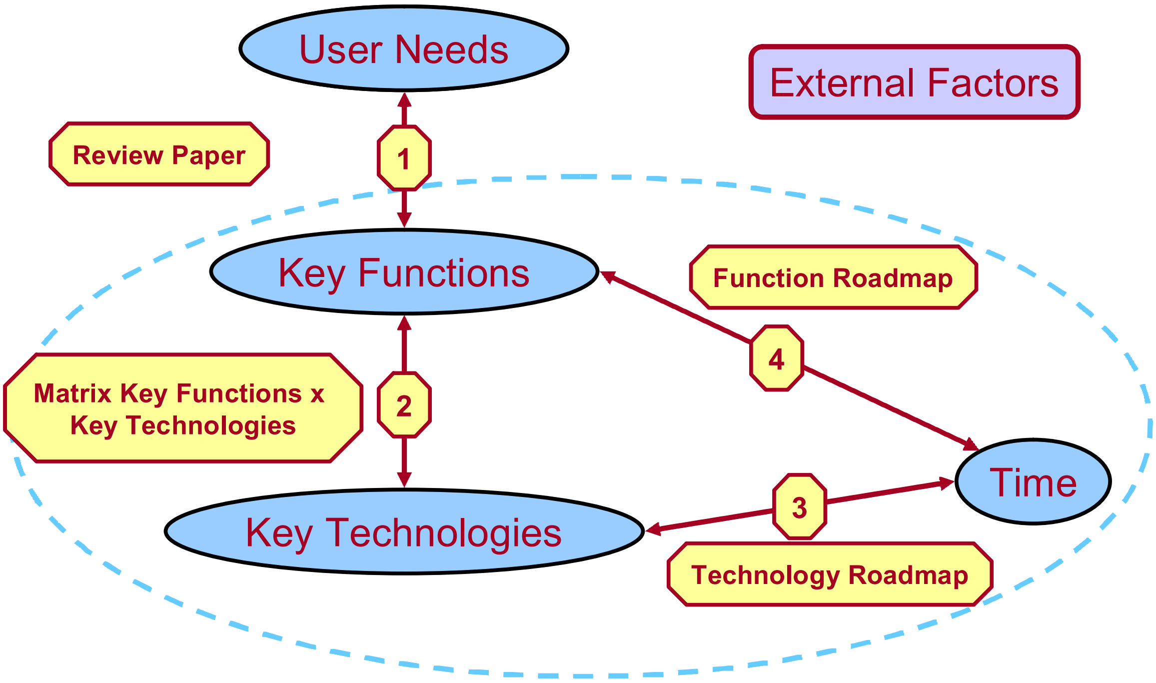


Figure 1: Methodological Approach of the AmI@Life S&T Road

The approach used in the Healthcare Roadmap was similar. The project team examined the current situation (Footprint Matrix) and a future vision (Matrix 2020) across three main technological clusters (information and communication technologies, medical technologies and genetic technologies) in terms of six principal dimensions of healthcare delivery (promotion, prevention, diagnosis, treatment, monitoring and aftercare.

## 4.2. Key Success Factors

The final evaluation of a roadmap depends primarily on the client satisfaction. However the following issues are important.

### 4.2.1. Prioritisation

It is essential to keep the process focused. The temptation to scan exhaustively a functional or technological field should be avoided and the most important information should be highlighted. The challenges / functions / technologies have to be prioritised and only the most relevant ones should be selected.

### 4.2.2. Inclusion of Human Factors

It is essential that the policy-intelligence roadmap is centred on some of the major challenges society is facing rather than only pushed by technology and the technology developers. Therefore the 'challenge' and the human factors: economic, social, human and demographic dimensions have to be intrinsic to the roadmapping process. For instance research demonstrates that though people have access to innovative functions, there is no inherent guarantee that they will accept and use them [Punie 2003]. This is to illustrate that a thorough analysis of social (use and acceptance) and economic (costs & business models, effects of public funding) factors is essential before envisaging the impacts of S&T developments on everyday life.

This raises the difficulty of integrating qualitative information within a systematic 'quantitative' process. There is a natural tendency not to put more emphasis on the areas for which quantitative elements or clear and undisputable relations are available to the detriment of areas for which they are not.

#### 4.2.3. Transparency

It is important to ensure the legitimacy of studies, which may later be used to support major decisions in R&D policy. Therefore, the requirement for transparency of the roadmapping project should be considered early in the definition stage. This has various consequences for both the process and output.

1. The methods used and the process should be consistent and well-documented so that the project team could "learn from mistakes" and continuously improve and refine the process;
2. The format of maps should enable some evolutions and updates;
3. The procedure for selecting the participants to workshops should be transparent and documented in terms of backgrounds, expertise and skills.

To complement point 3, Kostoff and Schaller [2001] have also formulated the (theoretical) needs for the development process to be iterative.

> *"This process is somewhat paradoxical in that the appropriate expertise must be employed to develop a roadmap, but the appropriate expertise becomes fully known only after a complete roadmap has been constructed. An iterative roadmap development process is therefore essential."*

These needs may apply primarily to the technology roadmaps developed within companies or industry. In the context of the policy intelligence, a new roadmapping project on a different challenge might be better value for money.

#### 4.2.4. Reliability

Reliability and replicability are essential for the credibility of the products and the process. Even if roadmapping is dealing with uncertainty, this should not imply that uncertainty and randomness are part of the process. The transparency of the process is a pre-requirement for the reliability of the output.

Kostoff and Schaller [2001] put it as follows: *"To what degree would a roadmap be replicated if a completely different development team were involved in its construction? If each development team were to construct a completely different roadmap for the same topic, then what meaning or credibility or value can be assigned to any roadmap?"* They provide at least a partial response by saying that *"to minimize repeatability challenges, a large segment of the competent technical community should be involved in the construction and review of the roadmap".* This is obviously demanding in terms of resources.

#### 4.2.5. User-Friendliness of the Outputs

To avoid information overload of clients and stakeholders (foresight and S&T communities, industry, citizens…), the appropriation of the outputs of foresight studies is always challenging. The necessity to deliver the outputs in user-friendly formats should be integrated from the definition stage, the form being in this case almost as important as the content.

The output and especially the graphic representations should be relevant, synthetic and user-friendly. Detailed, compatible and validated documentation have to support these graphic displays.

However, it should be emphasized that reaching the adequate level of relevance, simplicity and synthesis is particularly challenging. It requires good knowledge and a profound understanding of the field. The first iterations are likely to be complex, 'comprehensive' and cumbersome.

The developers of roadmaps, or any other foresight study, should be aware that the presentation of the results has a strong impact. In the future, roadmaps should therefore be in multimedia format and accessible from the web. It is however important to remain realistic because elaborate displays do not compensate insufficient content.

## 5. Validation and Evaluation

### 5.1. General Considerations

Peer review steps could be built early within the roadmapping process for instance during workshops with external experts in order to validate the:

- Identification of key functions;
- Identification of key enabling technologies;
- Roadmapping of key technologies;
- Roadmapping of key functions.

A process of validation of the final output can also be implemented. It has to be carefully designed, as a comprehensive validation of every detail would require almost as much effort as the original project.

However, it is important to keep in mind that a roadmap developed for policy intelligence may be less ‘scientifically exact’ than a roadmap developed with a considerably larger amount of resources within and by industrial R&D teams. This, however, does not necessarily mean that it has less value. The objectives and users are different and the value comes from the vision at higher level of abstraction and from the inclusion of socio-economic and human factors.

By definition, a good ‘policy intelligence’ roadmap responds to the specific needs of the policy-makers, whether they are explicit or implicit. Therefore, the validation of the roadmap should be considered as much as an assessment of the relevance, a ‘market testing’ or a quality control rather than a pure scientific validation. The ultimate evaluation of a foresight study is whether the outcomes have been translated into actions and have triggered some changes within the client organisations.

### 5.2. Validation of the IPTS/ ESTO Roadmapping Project

The validation of the pilot phase of the IPTS/ESTO S&TRM project took place in May 2003. It was conducted by European Commission R&D officials and external experts. The outputs were considered to be good value for money “a solid piece of work”, especially in terms of the quantity of material. Both studies were regarded as particularly timely and addressing major challenges in the context of an enlarging Europe:

- It is highly important for Europe to be active in AmI, firstly because the roadmapping has confirmed the potential of AmI to improve the everyday life in many different areas and second because Europe should remain independent from the US technologically;
- The effective delivery of healthcare is a striking challenge in the context of an ageing society and an enlarging Europe.

It was even suggested that a “European way” of roadmapping was needed, where the social drivers would be the leading ones, whereas within the US way competition and competitiveness are the leading drivers.

However, it was also mentioned that there was scope for increasing the impact and the relevance for the clients and users by exploiting the bulk of the existing material more thoroughly. Useful, applicable and relevant results should be extracted from the perspective: “what does that mean for the policy makers?” and complemented by “bridges to make them operational”. Therefore, it was envisaged that a relatively small complementary project could maximise the added value of the whole investment by extracting the critical points and developing strategic recommendations for R&D policy. For instance the quantitative output could be complemented by visions and scenarios such as in [Ducatel *et al.* 2001], or trend building, or SWOT analyses (Strengths / Weaknesses / Opportunities / Threats) or cost / benefit analyses to focus the policy recommendations.

## 6. Conclusion

As a conclusion, good progress in the development of a systematic methodology to investigate the relationship between key functions, key technologies and time has been made. The identification of the functions, technologies and the timelines were derived from a careful and iterative process of analysis and synthesis of previous works and from brainstorming. It has been possible to highlight some applications of S&T technologies in terms of useful, accessible and trustworthy innovative functions. These functions are effectively the starting point and leading dimension of this roadmapping methodology, before key technologies and time. This is probably one the main specificities and added values of the output of this study compared to the existing corporate and industry roadmaps: the "function-oriented" approach seems to be closer to the user. However, the remaining question is how far this methodology is relevant and efficient for the study of the interrelationship between the technological and the human (economic, social, political and demographic) dimensions. Certainly, this methodology cannot replace scenario building in this respect but further theoretical developments could address the integration of different methodologies, qualitative and quantitative, into foresight studies. Similarly, more efforts are needed to integrate outcomes of foresight studies such as S&T roadmaps into the policy-making process.

## 7. Acknowledgements

The authors are grateful to Prof. Wolfgang Bibel for his comments on this paper, even they have not been all taken on board.

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