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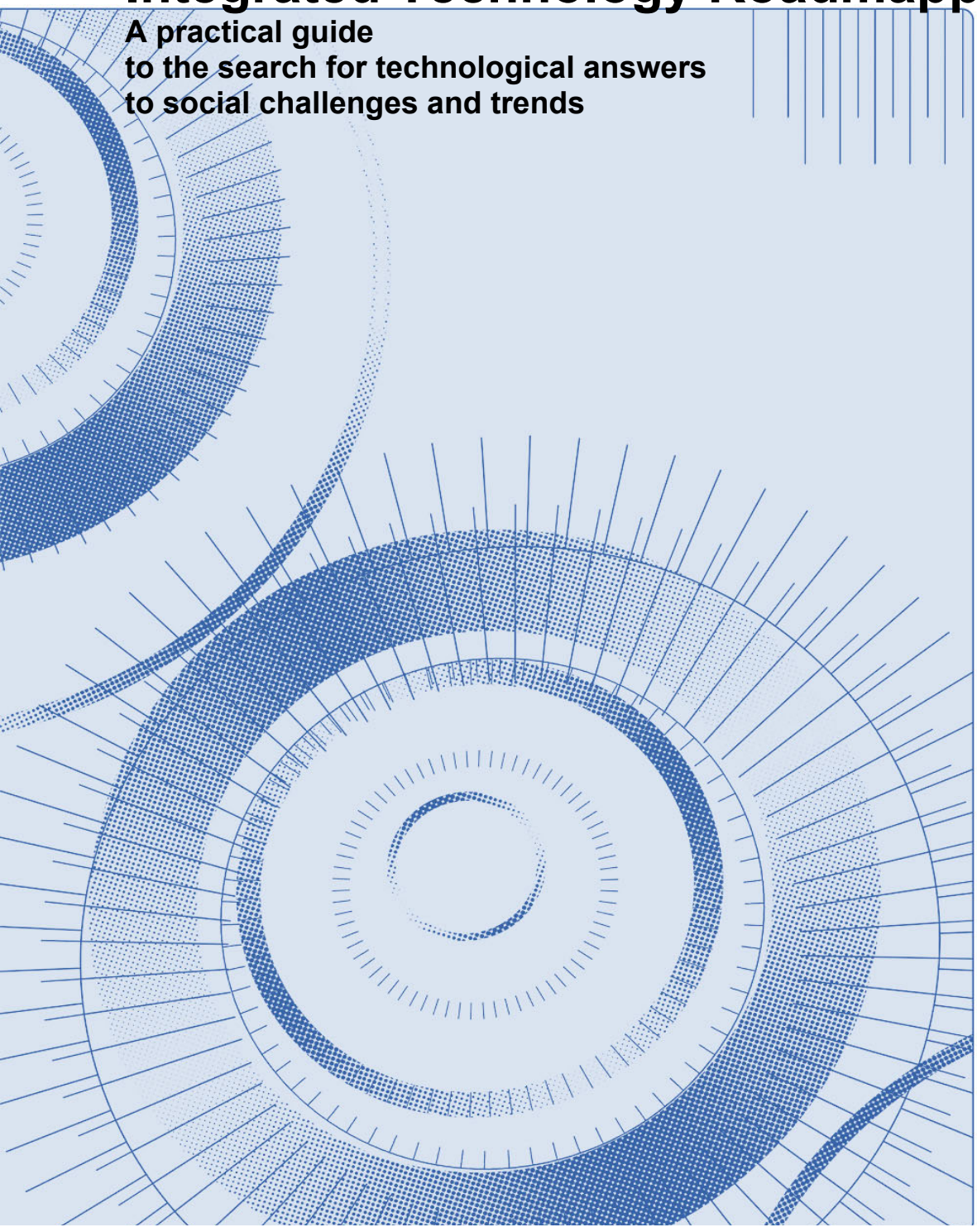
ZVEI

Integrated Technology Roadmapping

A practical guide to the search for technological answers to social challenges and trends



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1. Introduction

The increasing dynamism and complexity of business environments means that early recognition and monitoring of technological, market, political and social developments is becoming increasingly significant to innovative success.

In order to successfully identify innovation opportunities and risks, new business areas and markets at an early stage, the following core questions need to be answered:

- Which changes can be expected (trends, scenarios)?
- Which opportunities and challenges will these produce?
- Which future is desirable?
- Which disruptive events could occur?
- Which successful future strategies can be derived from this?

Roadmaps are an effective tool for answering these core questions. They are maps, in the broad sense of the word, which bundle together numerous individual topics, identify possible courses of action and set out priorities. Based on state-of-the-art technology, roadmaps supply information on the type, speed and direction of possible technological developments within an innovation context.

However, in view of the fast pace change of market, social and ecological developments, the restriction of roadmapping to providing technology forecasts is increasingly limiting its potential. Innovations are increasingly evading exclusively technological perspectives and commercial contexts which have been too narrowly defined. The point is not to project what is technically feasible, but rather to broaden our perspective by including socio-economic aspects and – a particularly important factor – by incorporating customer requirements at an early stage.

It is with this task in mind, that the Institute for Futures Studies and Technology Assessment (IZT) has developed the concept of the 'integrated technology roadmap'[1]. The integrated technology roadmap (ITR) allows several dimensions of promising business management strategies in dynamic technological areas to be examined simultaneously. It also looks for technological solutions to meeting social, economic, political and ecological challenges while shifting the main focus to the viewpoint of the user. Both of these methods help to minimise uncertainties about technology development, market launch and business models, and help steer decision-making in the right direction.

The concept has been successfully tested in cooperation with the ZVEI Fachverband Automation (Automation Association of the Electrical and Electronic Manufacturers' Association), resulting in the ITR 'Automation 2015+'. The procedure used to develop the ITR can and should serve as a reference for other fields of technology. This guide summarises the experience gained during the development of the roadmap.

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[1] within the framework of the German Federal Ministry of Education and Research's socio-ecological research programme (07IFS03A)

The guide is intended for the associations in ZVEI. Associations, being made up of groups of companies, are in the best position to carry out this complex procedure. They can provide the industry with an overall picture from which individual companies can then derive their own strategies. One of the key advantages of this method is its direct inclusion of customers and users. Customers are often more prepared to share their know-how with a group of companies than with one single company.

This guide provides practical tips and methodological support for developing an integrated technology roadmap with which to search for technological answers to market and social trends and challenges.

2. The basic concept

The basic methodological framework adheres to established technology roadmapping procedures. Firstly, existing trends are projected into the future. Secondly, scenario planning is used to envisage possible developments which go beyond these trends. Tasks and problems regarding the fulfilment of possible future market and customer requirements are then identified from the scenarios by projecting back into the present.

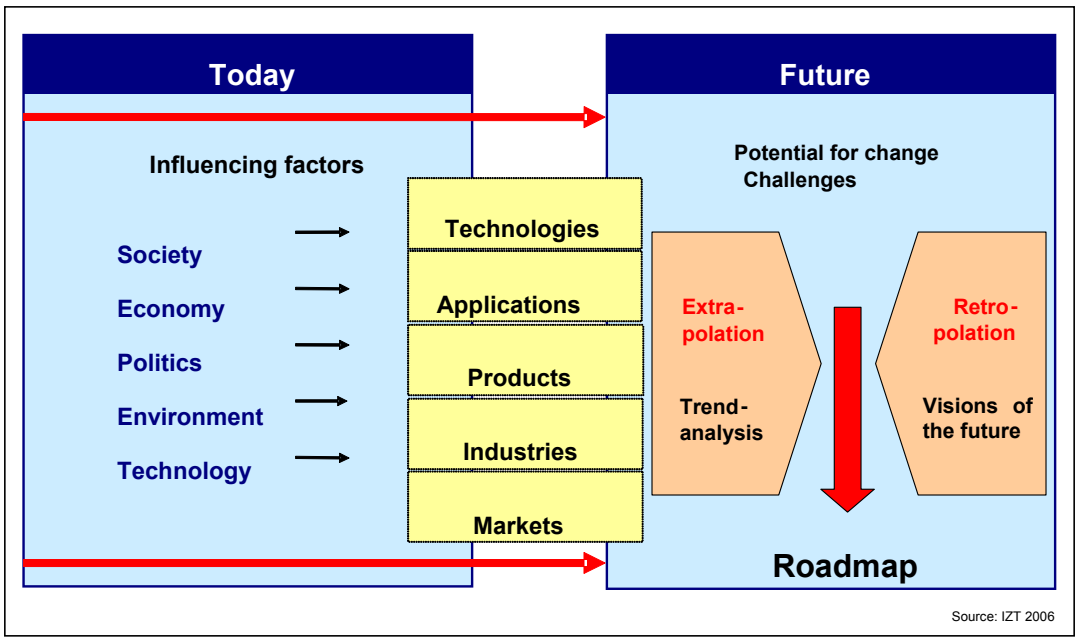


Fig. 1: Basic concept for the integrated roadmap

The different perspectives complement each other: while the trend analysis projects known developments into the future, tasks and problems related to today's innovation planning can be derived from the future scenarios. This combination of trend analysis (forecasting) and 'visions of the future' (backcasting) allow innovation options to be

bundled and translated into activities, requirements and milestones (i.e. into a roadmap) (fig. 1).

The integrated technology roadmap has several special features supporting the identification of technological, market and social challenges and potentials for change:

- Multidimensionality: several dimensions of promising business management strategies can simultaneously be examined from the point of view of innovative processes.
- Focus shift: the search no longer exclusively focuses on the dynamics of technological and market developments but also includes finding technological solutions to dealing with socio-economic trends and social challenges.
- User integration: the specific inclusion of external experts, customers and users is a major advantage.
- Side-effects: consideration of the side-effects and risks which technological developments may entail for companies, users and society.

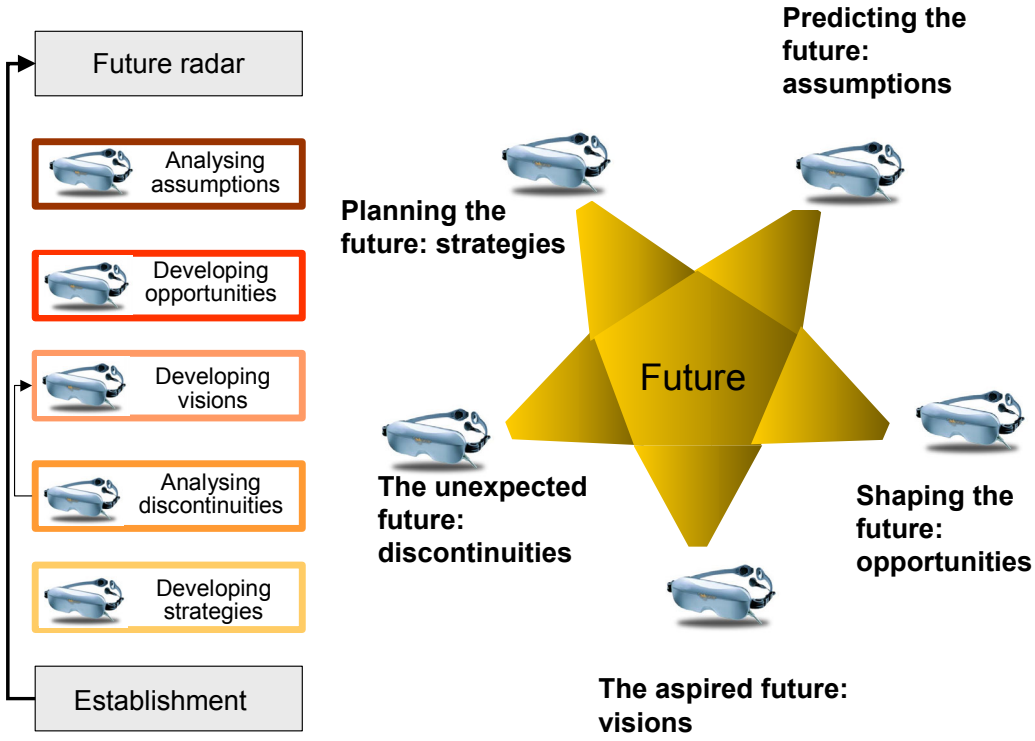


Fig. 2: Various visions of the future

Source: FutureManagementGroup AG

- Various visions of the future: the development of several scenarios from different perspectives (probable, possible, desirable, unexpected and deliberately created developments cf. fig 2), whilst taking disruptive events (wild cards) into account, in order to perceive the spectrum of alternatives and identify possible unexpected developments.

3. The five steps of integrated technology roadmapping

The roadmap is developed in a multi-stage process, beginning with the refinement of the search and ending with the identification of value adding options and challenges together with various activities to transfer and communicate the results. The steps required to create a roadmap are summarised in fig. 3.

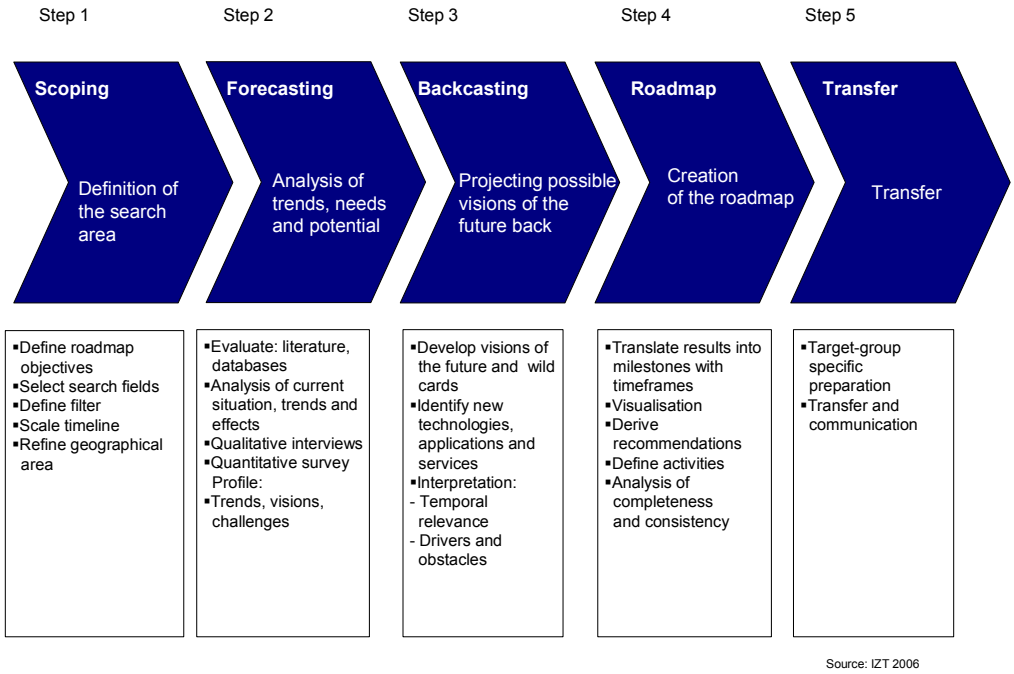


Fig. 3: Steps for creating an integrated technology roadmap

Step 1: Scoping: definition of the search area – target setting and system refinement

First of all, the search area has to be restricted to a reasonable size. It defines the reference points for the examination and evaluation of innovation trends and technologies. The purpose and objectives of the roadmap must first be determined, and further parameters must also be set regarding the temporal perspective, geographical reference areas, technological range and the market segments to be included.

Roadmaps can be kept very narrow in scope by concentrating on a short timeframe, individual technologies or market segments (using the search filter). They can, however, also be very broad and long-term in scope. There is no general answer to the question of optimum search area refinement; it must rather always be performed with a view to the objectives set as well as the capacities and resources available. The following parameters must be defined:

- Timeframe: short, medium or long-term perspective
- Geographical reference areas: Germany, Europe, other regions, worldwide
- Technological range: individual technology, technology fields
- Market segments: present-day market relevance, potential future markets, lead markets and niche markets, areas with strong or little consumer contact, technological trailblazers and stragglers, heavily and loosely regulated markets, areas with short and long investment cycles

A further important aspect of search area refinement concerns the procedure for identifying and evaluating the need for new technologies and applications as well as the potential they offer. As a rule, requirements regarding needs are identified using market analyses while the potential for change is incorporated into the technology roadmaps by analysing research and development.

The analysis of 'market pull' and 'technology push' is no longer a sufficient means of identifying strategic challenges and promising future areas at an early stage. Rather, the inclusion of further push and pull factors is necessary in order to identify and steer user-related requirements as well as any unintended health, ecological or social side-effects in good time. Of particular importance here are legal developments, social models, and the visions of proactive companies; the question of technological solutions for dealing with socio-economic and social challenges; the question of utilisation and functional systems rather than individual technologies or products, and the analysis and evaluation of new technologies and applications over the course of their life cycles.

Step 2: Forecasting: trends, needs and potential analysis

Forecasting aims to identify relevant potential for change. This cannot viably be achieved with a mere analysis and updating of trends, as is often found in technology roadmaps. Simple updating cannot adequately cover new challenges and possibilities with regard to technology and product development. In order to obtain workable results, methods must be employed and combined which allow the following:

1. Analysis of the starting conditions,
2. Identification of relevant trends and their effectiveness over time and
3. Exploration of potential for change.

A multi-stage procedure is best suited to meet these requirements. There is no silver bullet here, instead the mix of methods applied (e.g. interviews with experts, Delphi expert surveys, online manufacturer and user surveys) has to be adapted to the specific requirements made of the roadmap, depending on each individual situation. The inclusion of experts, users and stakeholders is of particular importance at this point.

Step 3: Backcasting: projecting possible visions of the future back into the present

Whilst forecasting projects known developments into the future as well as analysing and evaluating their interconnections, visions of the future allow tasks and problems regarding the fulfilment of possible future market and customer requirements to be identified by projection back into the present.

To this end, it is useful to generate different visions of the future based on a needs and potential analysis. Visions of the future are a representation of coherently bundled trends, visions and models. They are established tools within the areas of futurology and technology impact assessment and can be represented by means of scenarios.

It is also helpful to examine possible 'wild cards'. These are seriously disruptive events which upset structured plans and everyday routines. Although wild cards are an unlikely eventuality, their occurrence has far-reaching consequences.

With a view to the social challenges and needs, for instance, climate and resource protection, demographic developments, the demand for medical services or growing mobility and logistics requirements, more is required than a depiction of probable developments (in the sense of a forecast). It is also important to formulate possible, desirable or even undesirable visions of the future. A particular focus should be placed on the extent to which these developments can be shaped. By emphasising particular target determinants in alternative scenarios, visions of the future can be developed which clarify the opportunities and risks specific to each scenario and examine alternative courses of action.

In order to identify the challenges which are relevant in practice, it is of decisive importance to closely link the given scenario with the discourse of the relevant players. As part of the backcasting process, scenarios, visions of the future and wild cards must be subjected to an impact analysis by producers, users and other experts.

This is best done with the aid of group-based methods such as chaired expert workshops, user workshops and future workshops. Such methods provide opportunities for more effective exchange of information that reaches far beyond market signals and technology prognoses and also helps identify risks.

Step 4: Creation of a roadmap

In the fourth step of the roadmapping process, the results of analysis and evaluation are condensed and translated into milestones, activities and recommendations. The development of products, technologies and utilisation systems should then be clearly presented using a timeline. The generation of the roadmap should be followed by a review of the process. An internal review carried out by the group supporting or supervising the roadmap is usually sufficient. In the case of the 'Roadmap Automation 2015+', the review was performed by the companies represented in the ad-hoc working group together with the authors of the study.

The purpose of the review is to

- check whether all of the relevant developments were taken into account,
- establish whether the assessment of technologies and future markets is plausible from a factual and temporal point of view,
- assess whether statements made regarding trends stand up to scrutiny, and
- make assumptions and evaluations transparent and understandable for internal and external users of the roadmap.

During the review, uncertainties are identified and made transparent. To this end, the pool of data, the data quality, the steps in the procedure and the informational value of the results (e.g. given in ranges) must be checked. This should, above all, counteract the misuse in application which often occurs in prognoses. Particularly to be avoided is an exaggerated impression of the precision and relevance of the statements about the future.

Step 5: Transfer

Roadmaps are a tool with which future developments can be actively shaped. If they are to have an impact on innovation policy and management, they must be linked to operative activities. Special transfer activities must be included which are oriented towards the target groups concerned.

However, the full potential of roadmaps only takes effect once we have understood roadmapping as a process and implement it to support the early identification and monitoring of social, economic and technological developments

Fig. 4 shows how this general procedure was implemented in the ‘Roadmap Automation 2015+’ project.

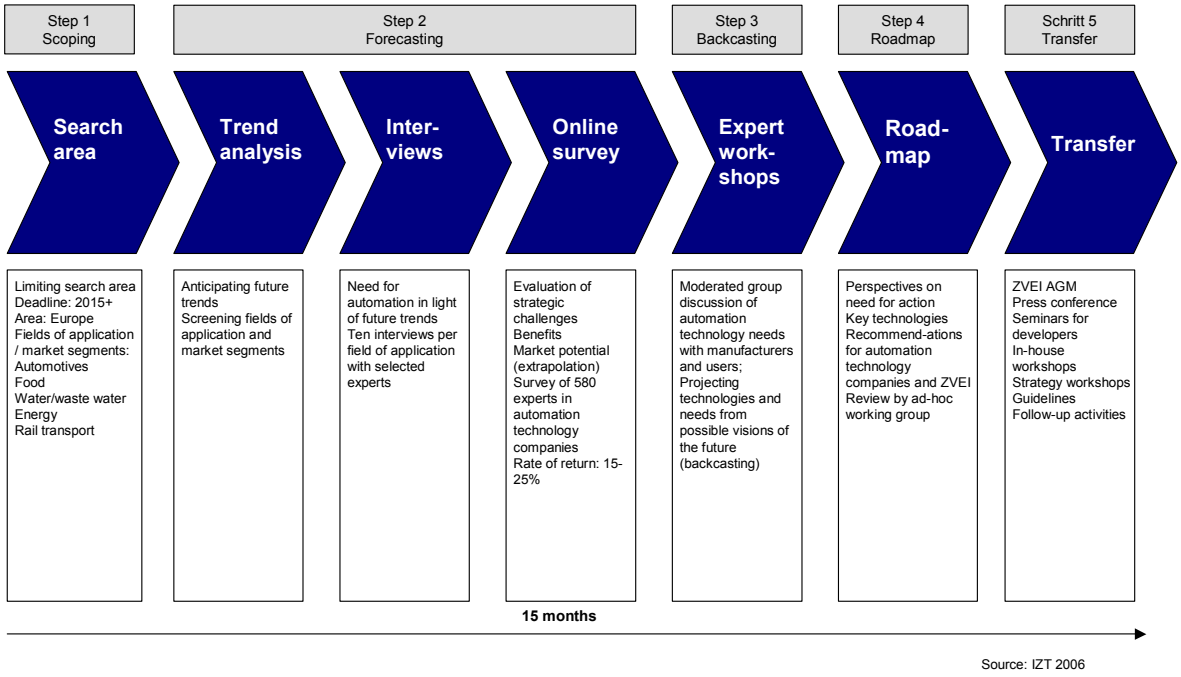


Fig.4: Steps for creating the Roadmap Automation 2015+

4. Practical tips

Enlisting an independent process coordinator with the relevant expertise and methodological skills

Overall management by an industrial enterprise or association committee has proved successful for many roadmapping processes with a narrow technological focus (e.g. in the semi-conductor industry). The companies involved generally contribute sufficient technology and market knowledge to the project.

In the case of the integrated roadmapping developed here, a project coordinator should be chosen based on a broader set of criteria with a different weighting.

- The examination of future trends beyond technology and market developments (e.g. social requirements) necessitates the involvement of a neutral, credible, external institution, as normative questions now enter into the roadmapping process. Only then can one be sure of a transparent and objectively justified search process.

- Opening up roadmapping to questions regarding social needs and possible future developments requires specialist expertise in these areas, which the process coordinator should have and should be able to provide.

- Experience gained in the generation of customer or application-related roadmaps has shown that the exclusive updating of

known trends is generally an insufficient means of dealing with complex relationships. The process coordinator should have adequate methodological skills and experience in futurology.

- In some roadmapping processes, an independent process coordinator is required if there is no established culture of cooperation, e.g. between the companies involved and state institutions. The independent process coordinator then acts as a door opener, brings the different players together and mediates if diverging opinions arise.

The contribution made by an independent third party must be financed by the commissioners of the roadmapping project. Such funding means that the financer must be afforded exclusive usage and – if the roadmap is to have an impact beyond the scope of the project – that a version of the roadmap with a modified focus should be made accessible to the public.

Search fields for innovations and future markets: linking mega-trends to technological developments and application potential

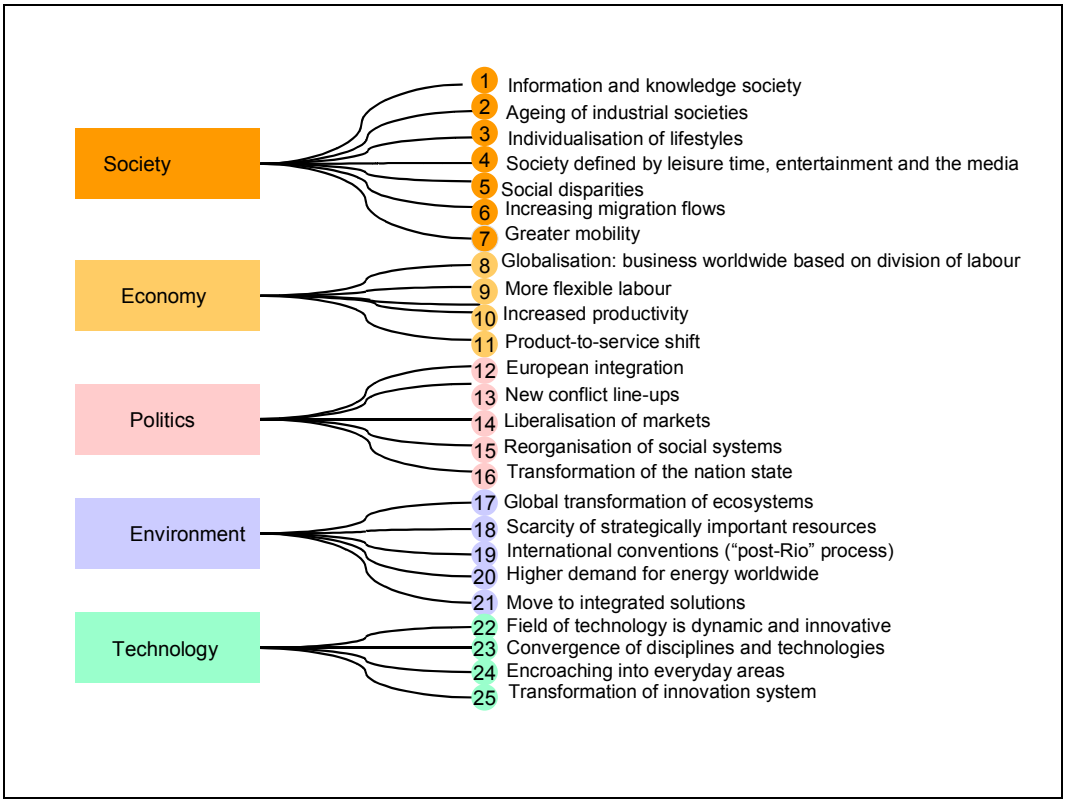


Fig. 5: Mega-trends

As regards future markets, one key question is how new technologies can contribute to solving future tasks in a way that presents companies with new value creation opportunities. Mega-trends generate long-term needs and can therefore be drawn upon as a means of orientation in the search for future markets (business areas, business cases). Whilst the list of mega-trends provided in fig. 5 is not comprehensive, it shows those social, economic and ecological developments which are highly relevant to technological developments.

In order to determine search fields, those mega-trends which are relevant within the context of the roadmap's objectives must first be specified and then linked to technological developments and application potential. There is, however no general, methodological recipe. Future markets for new technologies arise where social needs, customer requirements and technical possibilities can be translated into entrepreneurial models and strategies. Fig. 6 illustrates an example search filter for automation technology in the food, alcohol and tobacco sector. It provides a template for the generation of search fields and can, in modified form, be transferred to other fields of technology.

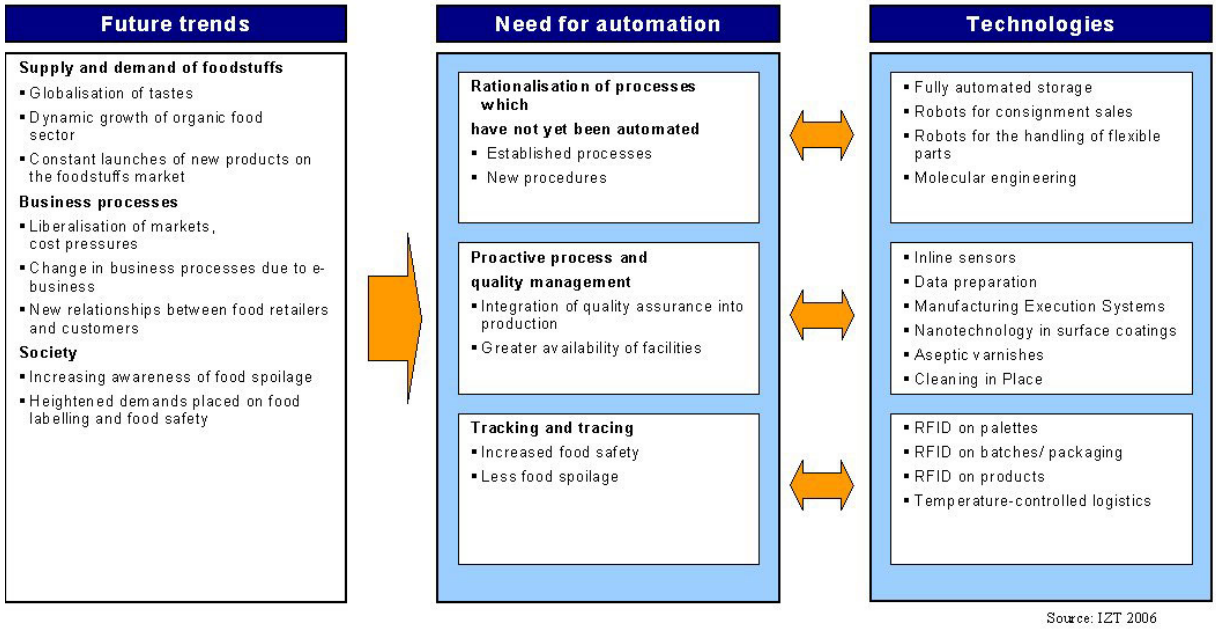


Fig. 6: Setting of search fields at the interface between social needs, trends and technological potential, using the example of 'food and automation technology'

Participation of dedicated industry experts and high-ranking decision-makers

The participation of dedicated industry experts and high-ranking decision-makers, and their inclusion in commercial or association-related decision-making processes are important factors for successful roadmapping:

- The participation of industry experts secures access to company and association knowledge.
- The inclusion of decision-makers ensures compatibility with companies' early-recognition requirements and innovation processes as well as the relevance of measures taken.
- Decision-maker participation facilitates later implementation of the roadmapping process.
- The involvement of industry experts and decision-makers supports transfer to companies or associations' working groups.

The ZVEI Automation Association set up an 'ad hoc working group technology roadmap' with the aim of generating a technology roadmap with a time horizon of approx. 10 years. The ad hoc working group was

made up of companies working in the automation sector and one of the association's members of staff.

The ad hoc working group initiated the creation of a roadmap and commissioned an academic futurology institute with supervising the process and generating the roadmap. The roadmapping process was then coordinated and steered by the ad hoc working group. The roadmap was financed on a cost-sharing basis by participating companies as well as firms which were not directly involved but which had an interest in the project. A chaired workshop held with the participating companies was used to define the search fields, fine-tune the targets and feed the process back in several loops.

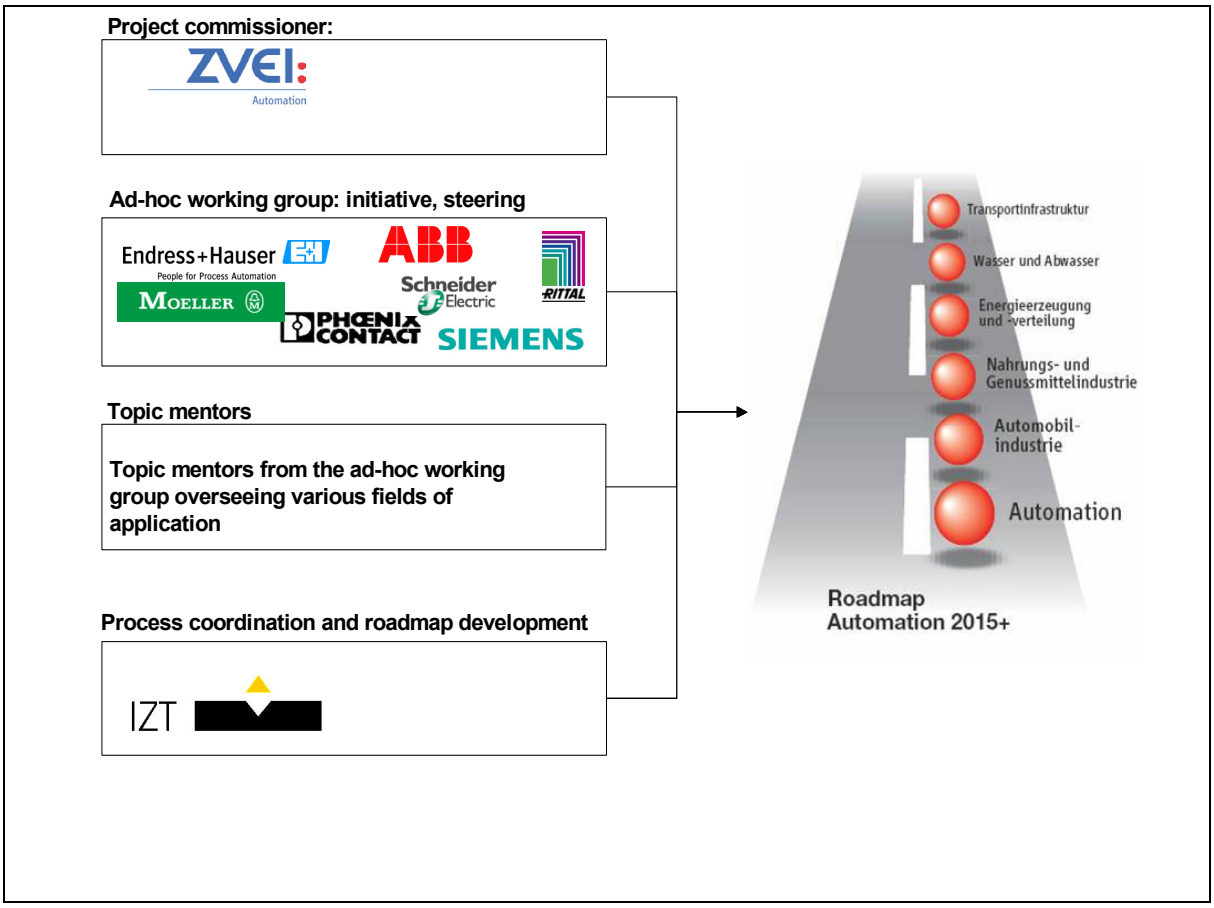


Fig. 7: Structure of the Automation 2015+ roadmap

Special 'topic mentors' were appointed from within the companies to oversee the analysis of various fields of application (automotive production, the food, alcohol and tobacco industries, energy production and distribution, the rail transport infrastructure, water and sewage – carefully chosen areas which represent the great variety of possible operating conditions for automation products and solutions). This method proved successful and can be recommended for similar roadmaps.

The mentors' task was to reinforce specialist expertise in the fields of application concerned, to fine-tune certain aspects such as questionnaires for online surveys, and to open doors, e.g. by obtaining expert interviewees from user companies. Meanwhile, the working group provided an important interface between the companies, ZVEI working

groups and the ZVEI board, ensuring the flow of information and supporting the transfer of the roadmap results.

Broadening the technological perspective: participation of users and external experts

The participation of specially qualified, visionary experts from relevant application areas at an early stage of the technology forecasting process contributes substantially to knowledge generation. This is, firstly, because innovative technological solutions can only become established if they fulfil needs and demand. Secondly, it increases the amount of knowledge, creativity and imagination employed in identifying technological potential and future markets, while also introducing the aspects of desirability, shapability and implementation into the roadmapping process, which are particularly important for any given technological development.

This achieves more than simply widening the horizons of the roadmap. Those who are directly affected, such as customers, can also be authentically involved in the early stages of innovation processes. Dialogue with users during the knowledge production process (R&D) and during the introduction of new technologies can help to reduce risks.

In order to integrate users successfully, we must bear in mind that the group of users is not homogeneous and that not all users are suited to active involvement. Before selecting users and external experts and integrating them into the roadmapping process, their function and role should be clarified (user experience, formulation of requirements, supply of ideas etc.). It should also be taken into account that different users (representative users, extreme users, end customers, lead customers, users from analogous areas, experts users etc.) are suited to different innovation tasks (idea generation, concept & design, prototype and product testing).

The search for and integration of users and other experts is by no means a trivial task, but rather a challenge. The selection of users and external experts must meet certain criteria (e.g. institution, specialist expertise, visionary skills). If these criteria are not met, the danger arises that the statements and evaluations generated will be arbitrary and will not guide the roadmapping process in the right direction.

There are various different ways of recruiting users and experts:

- The use of existing contact with users and experts with specialist and visionary skills is the most obvious option. However, experience has shown that this method alone is not sufficient.

- A further option is the networking approach. Initially, a few users and experts are contacted directly and asked to provide further users and experts who correspond to the criteria defined. People can then be selected from the list of experts thus compiled.

- The experts' skills can be determined with some preliminary questions over the telephone.

Experience has shown that it is not easy to recruit users and experts. Their willingness to participate depends on whether or not they see the chance to personally gain information from the dialogue between manufacturers and users. The amount of effort involved should be kept as low as possible: very frequent sessions tend to put people off and should be avoided in preference of attendance at one-day events.

Generating knowledge from different perspectives

Integrated roadmapping must be able to deal with very complex innovation conditions which can only be determined to a certain degree. Every effort should be made to gain a very broad understanding in order to identify key areas without getting lost in details. In many cases, it is better to adopt different perspectives, rather than to employ the same resources using just one method very accurately. We therefore recommend combining at least four perspectives:

- **Document analysis:** countless studies analysing trends, formulating visions and identifying technology potential are undertaken on technology application fields, e.g. mobility. Meta-studies, which are published by technology and futurology establishments such as the EU Commission's Institute for Prospective Technological Studies (IPTS), often condense information from numerous individual studies. High quality criteria and political relevance make such studies a good starting point. We therefore recommend looking for and evaluating high-ranking future studies, e.g. those undertaken by the United Nations or the European Union.

- **Expert interviews:** the complex interaction between drivers, future trends and technologies is best investigated with the help of interviews. Questions should be put to selected experts from within the user group. The series of interviews should include experts at various points in the value creation chain. It is useful to supplement interviews with the expertise of representatives of relevant industry associations, administrations and research institutions. It is by no means easy to identify interviewees who have a visionary way of thinking. As a rule, ten interviews should suffice to identify significant trends and needs.

- **Supplementary survey:** we recommend carrying out a second, broader survey in order to lend greater legitimacy to the conclusions gained from the document analyses and expert interviews. The survey should be open to identifying new aspects and, in particular, to supplying quantitative evaluations regarding prioritisation, benefits, market potential and other aspects. Support from an industrial association or the availability of a database of addresses is essential here. The survey is performed online, for practical purposes, substantially reducing the time and effort involved (fig. 8 provides an example).

- **Workshops:** workshops which bring manufacturers and users together are particularly well-suited to the discussion of future visions for technologies. The participants should cover a broad spectrum of expertise, representing the areas of research, development, innovation management and business

management. It is especially important to include decision-makers with strategic skills in the process.

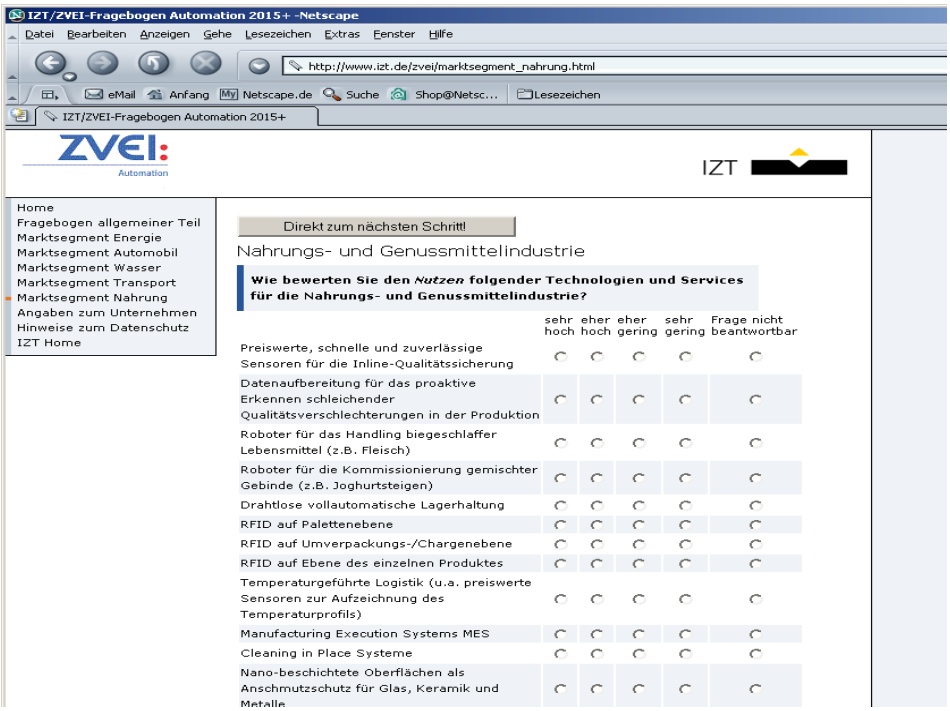


Fig. 8: Example of an online survey conducted for the Roadmap Automation 2015+ (screenshot)

The depth in which all of these forms of access can be analysed will be limited by time and budget restrictions: the number and depth of analysis of the meta-studies, the number of experts interviewed, the survey population and the number of workshops. The suitable scope will largely depend on the heterogeneity of the research object. A step-by-step procedure can easily establish from which point onwards no new knowledge can be gained, e.g. from further interviewees. In general, the degree of uncertainty should be made transparent. The combination of qualitative and quantitative empirical input will contribute to making the conclusions more understandable and more credible.

Temporal estimations are key to the roadmapping process. They are either made in workshops or in surveys. Temporal estimations made in workshops are bound to be more approximate than those made in surveys, particularly Delphi surveys where interviewees completing the second stage are confronted with statistical values from the first stage. However, estimations made in workshops are considerably less time-consuming. Group discussions make it easier to identify drivers and obstacles influencing the actual realisation of technologies, providing information on which courses of action to take.

How should uncertainties be dealt with? Visions of the future and wildcards

The early recognition of technologies and future markets together with related challenges is based on the analysis of trends and the identification of driving forces. However, statements made regarding trends involve particular uncertainties. On the one hand, this is due to a lack of knowledge of the possible course which complex, inter-related

development processes will take and, on the other, to uncertainty regarding social developments which cannot be anticipated but which, rather, are subject to social construction.

Mega-trends, such as globalisation or demographic change, reflect long-term developments (10 to 30 years), cannot be influenced to any great extent and affect almost all areas of life and the economy. Even if they are not ubiquitously prevalent to the same degree, they are still very comprehensive in scope. Mega-trends cannot simply be depicted linearly at technology level. It is not until they are placed in an application context that highly plausible new technology needs and requirements can be derived from comparably stable medium and long-term trends. Nevertheless, these trends, which are perceived to be stable, can either be dramatically accelerated or obstructed by so-called disruptive events or sudden breaks in trends.

In order to deal with this inherent uncertainty about the future, roadmapping employs scenario techniques, visions of the future and wild cards. These tried-and-tested ‘non-knowledge management’ methods and tools for reducing complexity in the early identification of technologies allow the course of possible developments to be identified (together with users and manufacturers).

- Scenarios: scenarios are future developments that are consistent in themselves. These dynamic projections allow roadmaps to evaluate those options for action which present themselves in the present day. ‘Extreme’ scenarios span a range of options for shaping events and taking action, and allow the strategic implications these would have to be better understood.

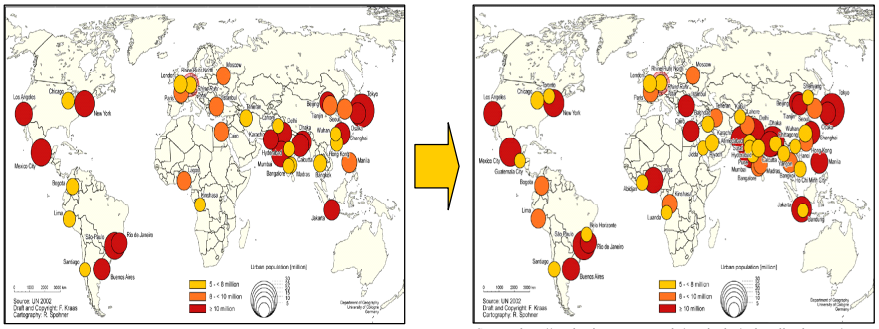
- Visions of the future: visions of the future are a snapshot of possible futures. They are generated by consolidating trends, visions and models.

- Wild cards are serious disruptive events and breaks in trends, which upset structured plans and everyday routines. Although wild cards are an unlikely eventuality, their occurrence would have far-reaching consequences.

The following examples from the integrated technology roadmap Automation 2015+ illustrate one vision of the future concerning ‘water supply and sewage disposal in mega-cities’ (fig. 9). They also list possible wild cards which may occur for the automation sector (fig. 10).

- Increasing urbanisation 2006: 50% of the world's population live in cities, 2030: 70%
- Emergence of mega-cities with over 10 million inhabitants
- Water becomes a scarce resource: today 5% of all people are affected by lack of water, in 2050 as many as 32%
- Climate change aggravates water problem (global warming, more semi-arid land, desertification)

2000 2015



Source: http://academic.evergreen.edu/curricular/culturallandscapes/maps.html

Fig. 9: Vision of the future concerning water supply and sewage disposal in mega-cities 2015+

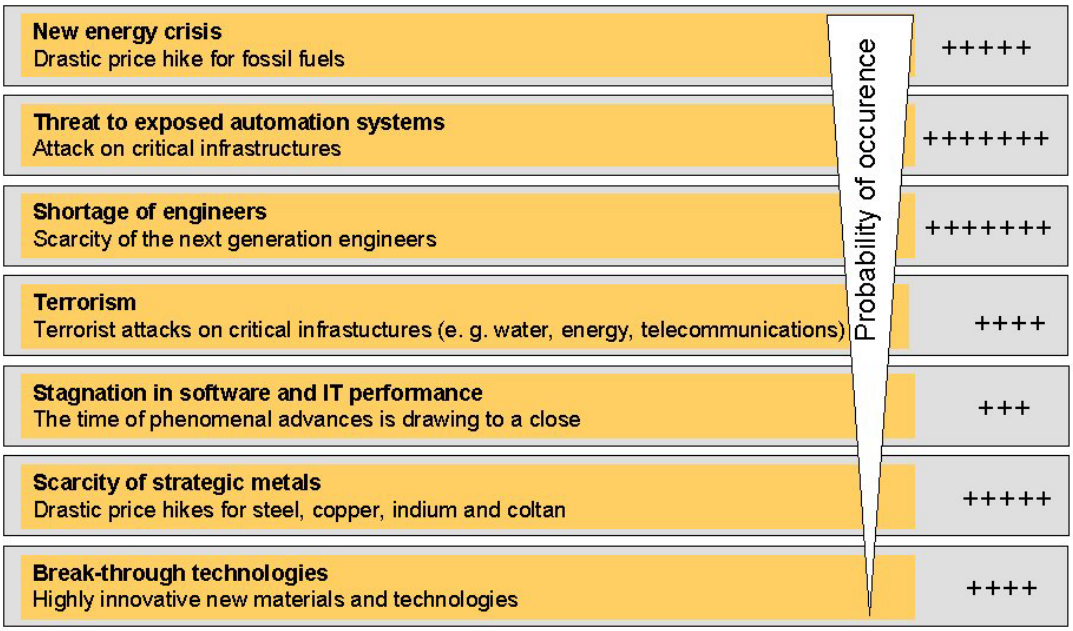


Fig.10: Possible wild cards and their significance for automation technology

Taking account of possible side-effects and risks

Technology-driven roadmaps are usually oriented towards technical feasibility. The end-product perspective also places functional requirements on the technological development. However, the technological development also throws up questions regarding opportunities and risks as well as any undesirable consequences which the technology may have. The growing dependence on technology, control over new media, the protection of the private sphere and unclear consequences for health and the environment all represent innovation management challenges which have, as yet, received little attention. Tackling these challenges requires an effective means of identifying technological and social developments at an early stage, the performance of complex life cycle and system analyses, the early evaluation of health and environmental threats, close cooperation with development and market partners and the integration of the relevant stakeholders into the innovation process.

Technology assessment broadly answers the question as to which opportunities and threats are associated with a technological development. These include questions of safety and acceptance, for instance. The basic idea is to feed technology assessment results into the innovation process, if possible from the initial idea through to the actual innovation. This offers the opportunity of focusing on threats and undesirable side-effects at an early stage (i.e. before the projects develop their own momentum), as part of the roadmapping process. The early focus is important here because once projects have entered later stages they can no longer, or can hardly, be amended, particularly due to cost concerns.

When dealing with the roadmapping process – a process which is already very complex – it may be tempting to dispense with the similarly complex assessment of side-effects. However, the evaluation of side-effects contributes valuable information to the roadmap about obstacles to the acceptance of new technologies and their implementation.

- The process coordinator will preferably have a broad understanding of the opportunities and threats held by new technologies. These can then be incorporated into the roadmap as possible drivers or obstacles which must either be fostered or removed.

- If sufficient, usable foreknowledge of the opportunities and risks linked to new technologies is not available, explicit reference should be made within the roadmap to the need for an innovative technology impact assessment.

In view of the large amount of time and effort which comprehensive technology evaluation involves, we recommend dealing with the side-effects of promising technologies in a pragmatic way. Pragmatic, here, means that approximate assessments and prioritisations should be made, as more detailed analyses can be performed during later phases. In any case, a roadmapping process should always be embedded within broader strategies for identifying technological developments at an early stage.

Using various forms of visualisation as communication tools

Social processes take on a particular significance in the integrated roadmapping procedure. This is due, among other factors, to the different stakeholders, perspectives and disciplines required for its development. The following elements, amongst others, necessitate agreement on all sides and should therefore be supported with visual aids:

- A joint definition of problems and targets should be developed. Flipchart-based prioritisation processes are a good way of establishing consensus and dissent during the required focus on specific sub-themes.

- Common forms of visualisation should also be drawn upon as a basis for discussion in order to identify solutions and temporal sequences.

One of the particular advantages of roadmaps is that they can clearly illustrate technologies, objectives and milestones using a timeline. This applies to integrated technology roadmaps and conventional technology roadmaps alike.

There are an abundance of ways in which the roadmap can be presented, each of which should be chosen depending on its suitability for the respective objective. The formats available include portfolios, the presentation of technology fields in segments using a timeline, flow charts or target depictions (milestones). An example is provided in fig. 11.

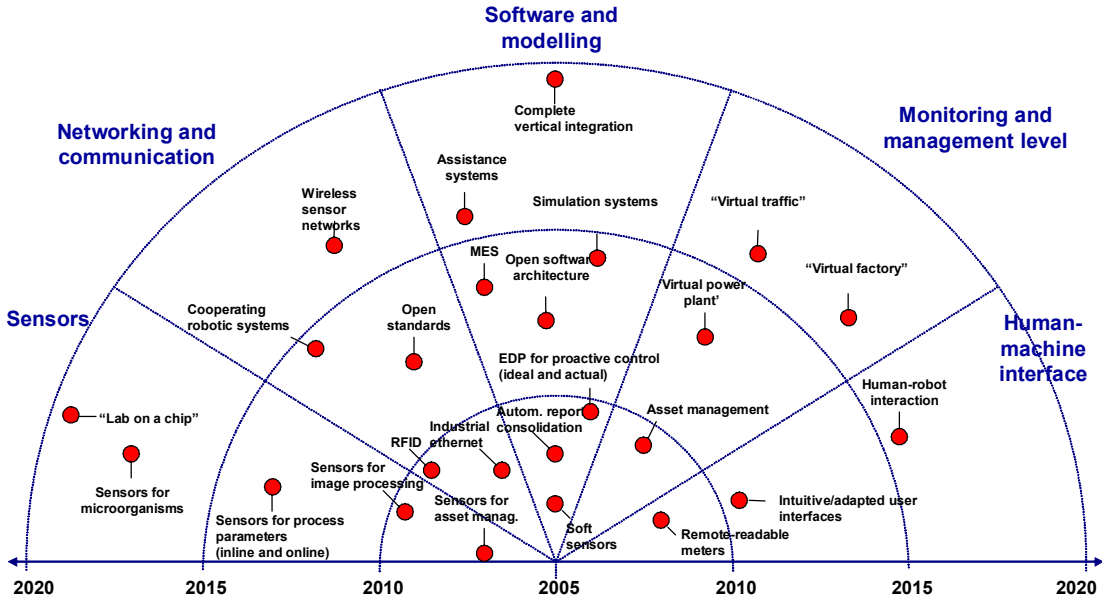


Fig.11: Presentation of technology fields in segments in the roadmap Automation 2015+

One special feature of integrated roadmapping is the derivation of technological requirements from socio-economic trends and social needs. This significant aspect not only demands specialist and methodological skills but also a degree of know-how which can only be visualised with great difficulty. A simplified schematic overview can, however, be used to support the process coordinator in the important task of translating this knowledge into images.

While conventional roadmaps have the advantage that they can be communicated easily, this is largely due to their implicit, mostly deterministic, one-dimensional vision of the future, which jars with the open, multi-dimensional concept behind integrated roadmapping. The consideration of different visions of the future and a correct reading of the roadmap are therefore of great importance.

Opening up to social stakeholders

Technology-oriented raodmapping normally does not require the inclusion of social stakeholders such as NGOs, foundations or consumers. Consequently, such roadmaps can predominantly be developed using specialists from the manufacturer and user sectors.

Integrated technology roadmapping necessitates an expansion in scope: it is often advisable to involve social stakeholders in order to help identify future markets, assume corporate social responsibility, tackle possible risks credibly and make solutions which contribute to sustainable

development visible. Their inclusion is also something which is actively called for from various standpoints.

In practice, however, this requirement clashes forcefully with the necessity of working professionally and rapidly on the roadmap. This is due to different spheres of interest and, in part, to widely differing expertise, both of which make agreement and understanding between the various participants difficult. The following procedure therefore suggests itself:

- If possible, the process coordinator feeds the positions held by the stakeholders into the roadmapping process. Consensus and dissent are recorded and shown in the roadmap in an action-oriented manner.

- Stakeholders are not included in the entire process but rather on a situation-by-situation basis. It is thus possible to ensure that people with the right skills participate in individual workshops, for instance.

- The personalities of the individual stakeholders should be taken into consideration during the selection process. Roadmapping requires people who are able to take a constructive, creative approach.

The behaviour of civil society groups in particular (e.g. NGOs) is subject to strong cultural influences. As a result, the participation of stakeholders can function perfectly smoothly in some countries, provided that they have a well-developed culture of cooperation, whereas confrontational attitudes can obstruct the roadmapping process in others.

The active, target-group oriented transfer of results

The roadmap offers an informational basis for the early identification of technological needs, user requirements and the prerequisites for tapping into future markets. If the roadmap is not intended for a small group of people, but, rather, broadly addresses a large number of companies and other players, transfer should be oriented towards target groups. Consequently, the relevant target groups should be established as early as the roadmap planning stage. The most important target group is often made up of those responsible for innovation management within companies. However, customers and associations' working groups can also represent key target groups. The target-group specific distribution of results demands an appropriately differentiated definition of key content. This will guarantee the interest of the target groups.

Several measures should be considered with a view to distributing the finished roadmap:

- Publication of a roadmap in an easily readable, condensed form.

- Making the roadmap available online for downloading provides for greater distribution than a printed publication would enjoy.

- Presentation of the roadmap to individual target groups (e.g. press conference for specialist journalists, annual association meetings)

- Offer of active services, e.g. on the part of the association in cooperation with the business coordination team in order to communicate the results of the roadmap in the form of in-house workshops.

5. Integrated technology roadmapping checklist

The following checklist provides a summary of all the important practical tips contained in this guide. It can be used as a basis for developing an industry-oriented or association-specific integrated technology roadmap.

1. **Involving an independent process coordinator (or coordination team) with specialist expertise and methodological skills**
   - Neutrality and credibility of the coordinator ✓
   - Specialist expertise regarding the industry/fields of application ✓
   - Methodological skills (coordination and chairing, surveys) ✓

2. **Defining search fields for innovations and future markets**
   - Develop a common definition of problems and objectives ✓
   - Establish time horizons: short, medium or long-term perspective ✓
   - Determine geographical reference areas: Germany, Europe, other regions, worldwide ✓
   - Define technological scope: single technology, technology fields ✓
   - Select market segments ✓
   - Include important push and pull factors ✓

3. **Including dedicated industry experts and high-ranking decision-makers**
   - Establish an ad hoc working group made up of business and association representatives ✓
   - Ensure specialist expertise with ‘topic mentors’ from the companies involved ✓

4. **Expanding the technological perspective: user integration**
   - Involve specially qualified, visionary experts from application areas ✓
   - Select experts according to defined criteria ✓
   - Ensure that these experts will gain information by participating ✓
   - Limit time and effort involved for experts ✓

5. **Generating knowledge from different viewpoints**
   - Employ data collection methods which have been tried and tested and which do not require a great deal of time and effort for the analysis of trends and the identification of technology needs (interviews, online questionnaires) ✓
   - Combine qualitative and quantitative data collection methods ✓
   - Select interviewees and workshop participants according to defined criteria (visionaries, top decision-makers etc.) ✓

6. Taking uncertainties into account: visions of the future and wild cards

- Derive technology needs from stable trends within an application context ✓
- Do not create just one future, but rather several possible projections ✓
- Extreme scenarios to clarify possible courses and scope of action ✓
- Use wild cards to identify seriously disruptive events and their significance ✓

7. Don't ignore possible side-effects and threats

- Make a rough estimation of threats and unintended side-effects using a defined search filter
- Keep down the time and effort involved by employing a coordination team with technology impact assessment skills ✓

✓

8. Using various forms of visualisation as communication tools

- Illustrate technologies, objectives and milestones using a timeline ✓
- Choose display format according to objective: portfolios, presentation in segments, flow charts milestones ✓

9. Opening up to social stakeholders

- Clarify whether involving stakeholders will be of benefit ✓
- Identify relevant stakeholder groups ✓
- Include stakeholders on a situation-by-situation basis ✓
- Select stakeholders according to defined criteria (constructive approach) ✓

10. Active, target-group oriented transfer of results

- Publish the roadmap in easily readable, condensed form ✓
- Offer the opportunity to download ✓
- Target-group specific presentation of the roadmap ✓
- Active offer of services on the part of the roadmap working group or business association ✓

11. Ensuring continuity

- Implement roadmapping as the cornerstone of a continuous process aimed at the early identification and monitoring of technological developments ✓
- Arrange periodic reviews ✓

6. Further reading

Readers who would like to gain a more detailed insight into the proposals made in this guide and obtain other points of view may refer to the following interesting articles which provide roadmapping reviews as well as actual roadmaps.

Reviews

Behrendt, S.: 'Integrated Roadmapping – Unterstützung nachhaltigkeitsorientierter Innovationsprozesse in der Informationstechnik- und Telekommunikation', in: Pfriem, R. (Ed.): Innovationen für eine nachhaltige Entwicklung, Deutscher Universitätsverlag, Wiesbaden, 2006, pp 395-416
This essay provides a succinct but lively description of the different types of roadmap and the key elements needed to develop an integrated roadmapping method (described more extensively than in this guide).

Behrendt, S.; Erdmann. L.: „Integriertes Technologie-Roadmapping zur Unterstützung nachhaltigkeitsorientierter Innovationsprozesse", IZT WerkstattBericht no. 84, Berlin 2006
This report provides an overview of the use of roadmaps in innovation processes, illustrates various case studies and explains the concept of the integrated technology roadmap.

de Laat, B.: Conditions for effectiveness of technology roadmapping – a cross-sectional analysis of 80 different roadmapping exercises. In: 'Proceedings of the EU-US Seminar on New Technology Foresight, Forecasting & Assessment Methods'; Seville, 13-14 May 2004
This article is a very practical summary of the factors required for successful roadmapping, based on an empirical analysis of 80 roadmaps from the USA, Canada and Japan.

Phaal, R.; Farrukh, C.J.P.; Probert, D.R.: Technology roadmapping – A planning framework for evolution and revolution. In: 'Technological Forecasting & Social Change' 71 (2004) 5-26
This essay focuses on supplying an overview of the different functions, presentation formats and uses of roadmaps. The presentation formats are illustrated with figures.

Möhrle, M.G.; Isenmann, R.: Technologie-Roadmapping – Zukunftsstrategien für Technologieunternehmen. 2., wesentlich erweiterte Auflage, Springer-Verlag, Berlin-Heidelberg 2005
This is already the second edition of a collection of specialist articles looking at technology roadmapping from different perspectives.

Fichter, K.; Kiehne, D.O.: Trendmonitoring im Szenario-Management - Eine erste Bestandsaufnahme informationstechnischer Unterstützungspotenziale, Fraunhofer IRB Verlag, Stuttgart 2006
This report provides an overview of existing software products and other information technology tools which support businesses with regard to trend monitoring and, in particular, the early identification of technological trends, including roadmapping.

Roadmapping in practice

Integrated roadmap Automation 2015+
(http://www.zvei.org) The Fachverband Automation (Automation Association) in the German Electrical and Electronic Manufacturers' Association (ZVEI) has developed an integrated roadmap on automation together with the IZT. The roadmap 'Automation 2015+' established assessments and expectations regarding the future need for automation in important user sectors (automotive

production, the food, alcohol and tobacco industry, energy production and distribution, the rail transport infrastructure, water and sewage) of the automation sector. The roadmap also deals with a more general range of challenges.

Erdmann, L. und Behrendt, S.: From technology driven roadmapping towards sustainability-oriented roadmapping: development and application of an Integrated Roadmap; International Seville Seminar on Future-Oriented Technology Analysis: Impact of FTA Approaches on Policy and Decision-Making – Seville 28-29 September 2006, Proceedings
This article explains the application of the method developed by the IZT using the example of the 'Integrated Technology Roadmap Automation 2015+'.

Technologie-Roadmap 'Prozess-Sensoren 2005-2015' by GMA and NAMUR (http://www.namur.de/publikationen-und-news/fachinformationen/roadmap-sensorik) This roadmap identifies challenges and developments for sensors and measuring systems in the chemicals industry up to 2015. It was developed by a joint NAMUR and GMA (the VDI Association of German Engineers) working group. The roadmap brings user and manufacturer perspectives (i.e. market and technological standpoints) together.

International Electronics Manufacturing Initiative: Technology Roadmaps.
(www.inemi.org) The International Electronics Manufacturing Initiative (iNEMI) is a member-financed association of electronics manufacturers, based mainly in the USA. iNEMI undertakes regular roadmapping activities every two to three years. iNEMI's roadmapping procedure is based on the fruitful interaction between five Product Emulator Groups (PEGs) and 19 Technology Working Groups (TWGs).

IPTS/ESTO Science and Technology Roadmaps
(http://esto.jrc.es/docs/roadmapping.html) The Institute for Prospective Technological Studies (IPTS) is a European Commission institute which was set up for the early identification or technological developments. The European Science and Technology Observatory (ESTO) is a network made up of a core of 17 members from various European countries and an extended group of over 30 organisations. Both establishments develop technology roadmaps.