UNIDO TRAINING PROGRAMME ON TECHNOLOGY FORESIGHT

Practice on Roadmapping

Technology ForeSight

Prepared on the basis of the Module 2:
Technology Foresight Training – a Specialized
Course on Roadmapping 17-21 November 2008

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1. Introduction to UNIDO Technology Foresight Training Programme

The UNIDO TF Training Programme pursues efforts to develop national and regional capabilities to organize and conduct technology foresight programmes for countries in Central and Eastern Europe (CEE) and the Newly Independent States (NIS).

The courses are offered to professionals, officials and managers as well as representatives of enterprises responsible for applying foresight as an instrument for strategic decision-making in technology development, innovation and industrial policy.

During the courses, leading international experts, deeply involved in foresight exercises world-wide, deliver lectures and introduce participants to:

- principal foresight experiences and good practices;
- case studies as a reference and inspiration for organizing foresight exercises;
- guided hands-on exercises in organizing foresight programmes; and
- networking of experts and institutions in the region for TF initiatives.

2. Introduction to Technology Foresight Methods

There is a long history to technology forecasting and "futures studies", with waves of interest evident in the 1930s. Contemporary Technology Foresight is generally traced back to the early 1970s, when the Japanese government imported the Delphi method from the USA, as part of a strategic shift from "catching up" to a position of technology leadership ("Japan number one"). Japan established five-yearly Delphi surveys to inform its R&D priorities. While this was called a "Technology Forecasting" effort, there was also emphasis on raising awareness of future challenges and opportunities among those involved in technology development, including companies and financial institutions as well as policymakers.

As new tools were sought for European S&T policy (from R&D priorities to renew innovation systems), attention was focused on the Japanese experience. Borrowing from this experience to greater or lesser extents, Technology Foresight exercises were undertaken in France, Germany, the Netherlands and the UK in the early 1990s. The German and UK exercises were particularly influential, inspiring much emulation in Europe and beyond, and the EC promoted Foresight as a science and technology (S&T) policy tool (and also for regional foresight).

The use of the term "Foresight" is more than just a fashionable re-labeling. There are two common features that most of these exercises share (to a greater or lesser extent, and with differing emphases on one or the other) that differentiate them from many earlier futures activities. First, like earlier futures work, foresight does have substantial emphasis on **prospectives**. It looks beyond the immediate horizon into the next decade or beyond. Likewise, it goes beyond forecasting and prediction ("what will happen?") to more action-oriented analysis of alternative futures ("what could happen?", "how do we make this happen?"). Often the goal is to locate S&T opportunities and relate these to possible market developments and social needs.

Second, Foresight exercises are typically tied to **policy**. They are linked to decision-making rather than being ivory tower activities. They may provide background intelligence on major issues. They may be intended to bring systematic analysis to bear on priority-setting. With the emphasis on Technology Foresight, R&D funding priorities have often been of central concern. But numerous other issues may be addressed – including in some cases the very structure of the S&T and innovation system of the country, or in-depth exploration of specific technological challenges.

Third, Foresight exercises have typically emphasised **participation**. They move beyond the analysis of a very few people (though they may well use inputs from small expert teams – or larger pools of expertise).

They aim at participation in part for greater legitimacy, in part to achieve wider inputs of knowledge for the development of analyses and action plans. Wider participation can also help build networks and help mobilise actors around shared visions of the future.

A major rationale for many Foresight Programmes has been to help establish R&D expenditure priorities, going beyond compartmentalised and "path-dependent" approaches, and using more forward-looking and participative processes. They were typically mainly funded by government. (A great deal of voluntary participation is also typical, with busy stakeholders giving their time free or at low cost. Sweden's national Teknisk Framsyn exercise was actually sponsored by a mix of government, industry and academic intermediary organisations).

Establishing better communication within national systems of innovation has been another main rationale for technology foresight, especially in those countries where there is thought to be excellent research but poor translation of new knowledge into commercial goods and services. Thus, many of these exercises involved large numbers of participants from the worlds of research, policy, and business – with sometimes wider engagement with social movements and the general public. The process benefits of technology foresight – networking, agenda-building, creating more of a foresight culture – are harder to measure than the product benefits – such as reports, statistical analyses, priority lists. But they have become recognised as valuable in their own right and important in enabling high-quality products, and the implementation of the results of the exercise.

2.1 Overview of Foresight Methods

There are different Foresight methods and various approaches to make distinction between them. One of the most familiar is between exploratory approaches ("what happens if?"), and so-called normative ones ("how would this state of affairs be realised?"). Another inescapable distinction is between more and less quantitative and qualitative approaches.

The methods used in a Foresight exercise need to reflect the resources available and the objectives of the exercise. The choice of methods is critical, though it often appears to be based upon what is fashionable or which practitioners have experience in. The methods may be organised and interrelated in different ways – this is methodology, but there is little advice on the sequencing of methods. There are various guides to available methods and tools. Methods are used for a multitude of purposes, including:

- investigation of the long-term (e.g. trend extrapolation, simulation, Megatrend analysis, etc.);
- opinion elicitation (e.g. interviews, surveys, Delphi, etc.);
- deliberation (e.g. working groups and panels, workshops, conferences, public forums, etc.);
- creation and envisioning of futures (e.g. scenarios, essay-writing, science fiction, etc.), and
- determination of courses of action (e.g. technology road mapping, multicriteria analysis, various prioritisation techniques, etc.).

EFMN (European Foresight Monitoring Network) analyses suggest that exercises use, on average, 4–7 different methods as part of an overall methodology.

Below, we briefly outline features of some of these methods – some (literature review) seem fairly self-evident. Roadmapping, to be complete, is very much expertise-based and it is widely used in technology planning (especially in business).

SWOT Analysis

SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis is used to provide background inputs to Foresight activities. Sometimes main Foresight activities will also result in analysis presented in SWOT terms – this may, for example, come out of Delphi studies – but more usually SWOT is less based on an assessment of the longer-term. SWOT is often presented in a 2×2 matrix, an overview of significant internal and external factors influencing strategies or possible futures. It is usually prepared by an expert team using a variety of data sources and often a programme of interviews. Opportunities and threats are prioritised in terms of their importance and probability; strengths and weaknesses in terms of importance to performance to each factor, too. Graphical plots and other methods are used to select key factors. SWOT analysis is widely used, especially as a preliminary step in planning. The methods may also be used in workshops involving a wide range of participants.

Failures in SWOT analysis often reflect inadequate definition or prioritisation of factors. This may be due to an absence of real expert knowledge; the reiteration of standard analysis by consultants unfamiliar with local specificities; political pressures of associated desire to downplay regional/national weaknesses. It is also possible to underestimate one's strengths. Repeated disappointments may lead to local "common sense" becoming fatalistic and supporting the view that a region is inevitably disadvantaged in certain respects, failing to examine any evidence that suggests the contrary.

Benchmarking

Benchmarking involves comparing the activities (process benchmarking) and performance (target benchmarking) of one's organisation or region, with those of similar entities elsewhere. Such comparisons have a long history, but interest in using the approach systematically has grown especially as firms have sought to compare themselves with examples of 'best practice'. This has been transferred to the sectoral and regional or national levels, and to a wide span of policies as well as purely economic ones. It offers learning opportunities ("how do they achieve that?"), as well as scope for setting goals ("we will be up to that level by the year 2010") and identifying likely competitive challenges.

Benchmarking should not be (but often is) performed in a very reductionistic way, with performance in terms of individual indicators being abstracted from the systemic context of the organisation or region in question. It is important to examine the topic area carefully, so as to identify the most appropriate issues around which to build indicators, and to examine which of various indicators might be most useful (e.g. it may be more appropriate in some cases to weight a "raw" indicator in terms of the population size or even the size of a population subgroup such as elderly people, small firms, etc.)

Environmental Scanning/Horizon Scanning

Environmental scanning involves monitoring the organisation's business, political, or technological surroundings, with horizon scanning putting more emphasis on emergent (or even "weak signal") developments. The aim is to develop a view of where important new directions are taking place, what trends need to be watched, who the key players are and might be. Methods used here are very varied: they include systematic analysis of media (including the Internet), content analysis tools (to indicate emerging social attitudes and political movements), review of reports from financial analysts and specialised consultancies (to suggest emerging markets or business models); examination of specialised databases (e.g. patent or bibliometric data, to give warning of developments in science and technology).

Many organisations routinely engage in such scanning, but most often it is conducted in a "one-off" fashion when a new activity is being planned. This may save costs, but reduces learning opportunities. It is possible to become too tied to specific methods and data sources, so that alternatives – especially paradigm-challenging ones – may be neglected.

2.1.1 Creating Visions

Genius Forecasting

This uses the insights of a gifted and respected individual to provide a vision of the future. Such an individual will usually be drawing on the work of many colleagues, but be synthesising these ideas in a new way for the current circumstances.

Such work may often be dismissed as one person's viewpoint; few individuals have the span of knowledge required to cover a wide enough range of issues confronting us.

Trend Extrapolation

Trend extrapolation projects trends forward, usually by mathematical or statistical equation-fitting. Sophisticated methods of fitting logistic curves to data that are expected to evolve in an S-shaped pattern, envelope curve analysis to examine performance trends across generations of technology, and approaches to working from cross-sectional data to project time-series trends, are among the approaches used. Extrapolation can forcefully indicate the scale of change that would follow from a trend continuing into the longer-term; showing that small seeds may become big things that ceilings are liable to be reached, that surprising developments may be confronted.

It is important to identify what forces are driving a trend (and whether these will persist); and what assumptions about such forces are built into the extrapolation. Especially problematic are: inferring a trend on the basis of cross-sectional comparisons or very limited time series; assuming that ceilings will be reached at arbitrary points; failing to assess underlying driving forces adequately; not recognising that enough of a quantitative change usually implies qualitative transformation.

Expert Panels

Working under the Steering Committee, Panels of sectoral and/or technological experts are commonly used to commission and synthesise Foresight analyses. Panels may make a general overview of major issues, or be oriented to specific topics or sectors. They often play important roles in generation methods such as Delphi question formulation and scenario workshops. The main task of a Panel is usually that of synthesising a variety of inputs – testimony, research reports, outputs of forecasting methods, etc. – to provide a vision of future possibilities and needs for their topic areas. Implicitly or explicitly, methods must be employed to select and motivate the panel, assign tasks, and to activate them in the development and sharing of knowledge. Brainstorming and SWOT analysis are among the methods used in Panel work. Leadership and conflict management skills are required to maintain motivation and morale, and to resolve disagreements.

Panel work is highly significant to Foresight Generation: Gathering relevant information and knowledge; Stimulating new insights and creative views and strategies for the future, as well as new networks; (and later on helping to diffuse of the Foresight results and its general approach to much wider constituencies; to design follow-up action, promoting it, and overseeing its execution). Panels require open-minded and creative team workers, who speak as experts rather than as interest group representatives. Too narrow representation is liable to result in limited analysis, "capture" by interest groups. It is vital to retain legitimacy. Giving panels too much autonomy can create difficulties for synthesis of their outputs, combining their scenarios, reaching shared priorities, etc.

Brainstorming

Brainstorming is a widely used group method, aiming to reduce inhibitions about generating "wild" ideas, and to stimulate creativity and novel viewpoints. While the term is given applied loosely, the original definition refers to a process involving: a period of freethinking, which is used to articulate and capture ideas, with no critical comments; followed by more rigorous discussion of these ideas, typically involving grouping them and prioritising the most important themes.

Brainstorming is a starting point, and its output may be too rough to be directly used in reports, etc. A skilled facilitator is required to reiterate and enforce the ground rules so as to maintain openness and prevent animosity – especially where participants are inhibited or liable to express ideas that are offensive to other group members. Brainstorming may be supported by computer tools, though classically implemented through use of flipcharts on which to capture ideas.

Delphi Method

Delphi involves a survey of expert opinion – most commonly about when particular developments might happen, and often also about possible constraints and facilitating factors economic or social implications, etc. (Many other types of Delphi are possible: e.g. to help identify and prioritise policy goals, for example, but these have been applied quite rarely). Delphis are mainly conducted through postal surveys, but can be used within group meetings, and through computer- and Internet-based methods. The critical feature that makes Delphi different from other opinion surveys is that the survey is reiterated a number of times with the respondents receiving feedback on the structure of responses at previous rounds (and ideally information on why judgements were made). This is hoped to reduce dominance by the loudest or most senior figures, while allowing exchange of views and information.

Delphi studies provide impressive results if conducted well, but require careful and laborious: choice of participants, preparation of questions, and provision of feedback. Some so-called Delphis do not reiterate the survey or provide adequate feedback to respondents. Drop out rates may be high. Delphi surveys are fairly time-consuming and labour intensive. The task of preparing the questions can be a very helpful exercise for illuminating shared views and points of disagreement as to future possibilities: thus it is unwise to replicate the topics used in other studies.

Cross-impact analysis

Cross-impact analysis is a method in which experts rate the likelihood of various events occurring – and the likelihood of each event occurring if each of the others does or does not occur. Statistical processing of the data results in assignment of probabilities to the scenarios resulting from the combinations of events. This overcomes one limitation of methods like Delphi, in that they treat events as completely independent of one another. But the method requires the experts to make a fairly large number of difficult judgements about combinations of events – and it has to limit the number of these judgements, only a few key variables can practically be examined (thus the choice of events is crucial).

Relevance Trees and Morphological Analysis

These are probably the two best-known “normative forecasting” methods. They seek to identify the circumstances, capabilities, actions, and knowledge needed to achieve future objectives. A relevance tree subdivides a broad topic into increasingly smaller subtopics, in terms of a tree-like diagram. It sets out various aspects of a system, a problem, or solutions to a problem. Morphological analysis involves mapping “all possible” solutions to a problem, so as to determine different future possibilities. It has been used for new product development and in constructing scenarios. Both methods are tools for thinking systematically about the topic of concern, and can generate unexpected possibilities and new thinking.

These approaches require in-depth analysis, drawing on expertise in the problem fields, and involving lengthy and arduous work. They can provide powerful intellectual stimulus (even without the exhaustive analysis depicted in some classic examples), but still considerable inputs of time and critical judgement are required.

Scenarios

A Scenario is a systematic vision of future possibilities. This corresponds to the ways that the term is widely employed in Foresight work – as contrasted to theatre, software design, and various other specialities. The term systematic implies (a) internal consistency and (b) covering developments in a fairly holistic way, going beyond simply profiling the future in terms of one or two key variables, as might be the case in simple models and extrapolations. A scenario should present a more fleshed out picture, linking many details together. Typically these will combine quantifiable and non-quantifiable components.

Two common orientations of scenarios are:

- Future Histories – that outline events or trend developments and describe an evolving, unfolding future.

- Images of the Future – that are more focused on a point in future time, describing the future state of affairs at that time in more detail.

Often, both are developed, but many studies will focus more heavily on one or other element. A further, long-established, distinction in futures and forecasting studies is between approaches to scenario development (and futures work in general) that are commonly (if misleadingly) called:

- Exploratory Approaches, which start from the present and posing "what if" questions: What if the growth rate is x% or y%? What if events W or Z happen? What if one set of drivers takes precedence over another? What if we pursue one or other strategy?
- Normative approaches, which start with an idea about future developments (e.g. a profile) and asking "how" questions: How could a particular future or trajectory of development come about? What would it have taken to have reached a future where the parameter of interest is x% greater than its current value? What would have led us to situation Y?

2.1.2 The Debate Concerning Qualitative and Quantitative Approaches

Quantitative information (e.g. statistical data), once obtained, can be manipulated in consistent and reproducible ways that allow for precise comparison and estimates, checks on consistency, visualisation of data in graphs and charts, etc. in these ways. Quantitative methods are often used to provide some of the backdrop to a Foresight exercise, by indicating the range of assumptions we might have concerning key parameters, and thus informing scenarios and other approaches. Quantitative results are often particularly valued and attended to by policymakers.

But there are problems with such approaches. These include the danger of neglecting important factors that are hard to represent numerically. There is the risk of social exclusion: numeracy and similar skills are unevenly diffused: some people find it hard to read or work with data; and the most sophisticated quantitative methods require considerable expertise to apply and to deconstruct. Finally, there are dangers of "spurious precision", where "guesstimates" are treated as more weighty than they deserve to be.

Qualitative methods typically involve more of a narrative exposition, since they are based on inputs that are hard to summarise in a numerical form: even if we can count how often terms are used or associated with each other, we still need judgement to identify the sorts of linkage and relationship that are being addressed. For a long time qualitative approaches in social research were rather poorly systematised, with most attention devoted to "data capture" (how to conduct interviews or observe group behaviour, for example) and very little discussion of how the rich and often voluminous material that results could be analysed – it was as if this were mainly a matter of having a creative and insightful mind. Creativity and insight cannot be discounted, but the application of systematic methods to analysis of qualitative data has been documented in several textbooks, notably Miles and Huberman (1994). It is becoming increasingly possible to process qualitative data in quantitative ways, using automated coding and data analysis tools and software.

Mindmapping and Argument Analysis are methods, often aided with computer and software tools that require an experienced mediator to implement. They involve organising and visualising the subjects of group discussion, presenting these in ways that can help move the discussion forward. They involve grouping and linking ideas, drawing on the ideas expressed in the group. Experience with these methods is growing, and software tools are also evolving rapidly.

Conclusions as to best practice and best tools remain to be consolidated. The value of these approaches depends very much upon moderator experience – and may be influenced for better or worse by ideas developed earlier.

More information on foresight methods and their practical use to be found in UNIDO Technology Foresight Manual (2005) downloadable from www.unido.org/foresight.

3. Roadmapping

3.1 Introduction to Roadmapping – Background and Evolution

One of the definitions of a roadmap broadly used is as follows: „A roadmap is an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of change in that field." This definition emphasises the importance that knowledge and expertise plays in the process, the forward-looking nature of the approach, and its flexibility.

Many different approaches to roadmapping have been developed, and roadmaps can take many forms, although generally the focus is a graphical representation that provides a high-level strategic view of the topic of interest. The most flexible and powerful framework for the creation of roadmaps is illustrated schematically in Fig. 1, comprising a multi-layered time-based chart, bringing together various perspectives into a single visual diagram. This type of roadmap enables both 'demand' and 'supply' views to be represented, balancing 'market pull' and 'technology push'. This enables the views of multiple perspectives (e.g. functions, disciplines and organisations) to be mapped in terms of future developments and aspirations, and the relationships between those perspectives to be identified, with the associated communication benefits.

Roadmaps can thus be considered as dynamic business or system frameworks, which enable the evolution of a system to be explored and mapped, supporting innovation and strategy development and deployment at all levels (often hierarchies of roadmaps are used, to enable information at different levels of granularity to be displayed).

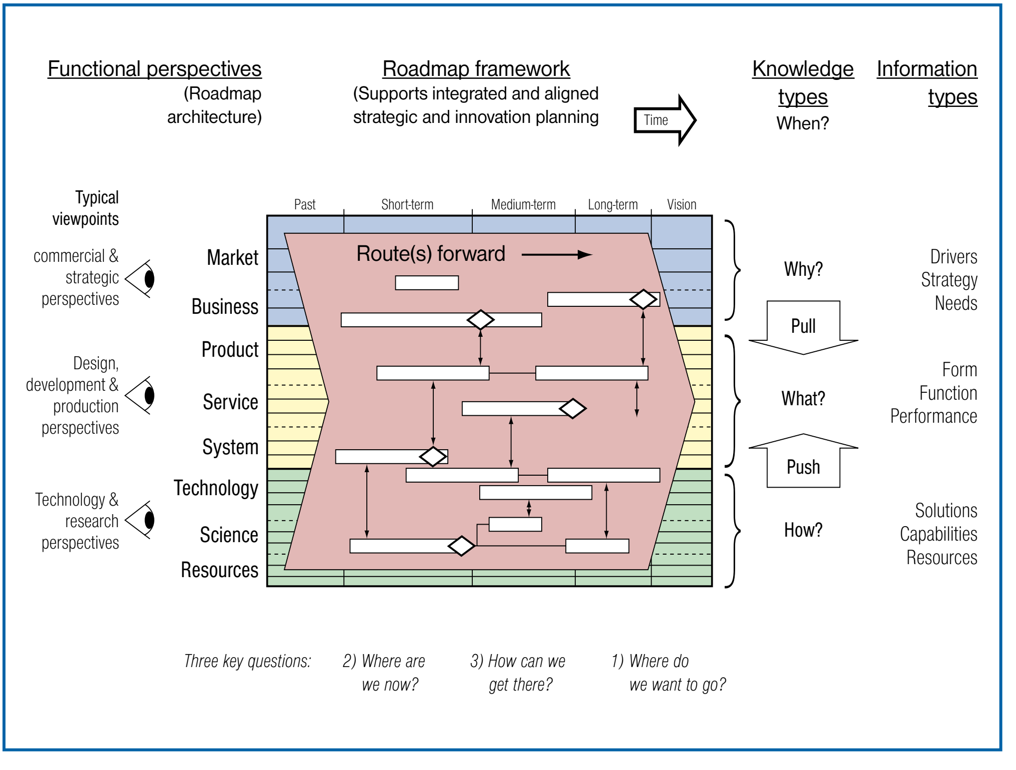

Fig. 1: Schematic multi-layered roadmap, aligning multiple perspectives

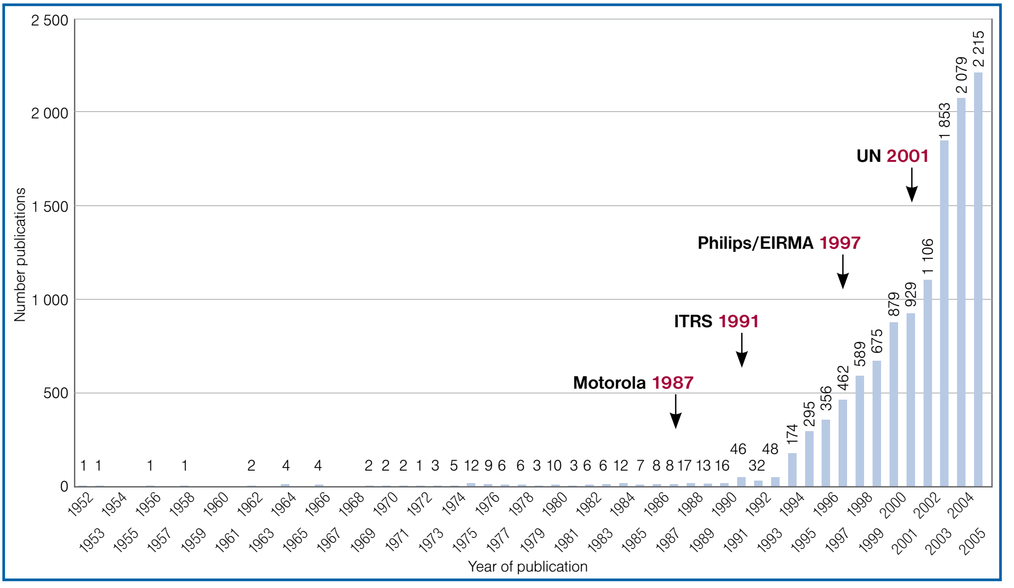

Fig. 2: Growth of published roadmaps *Source: Premier Database, Beeton (2007)*

This holistic roadmap framework links directly to fundamental questions that apply in any strategic context:

1. Where do we want to go? Where are we now? How can we get there?
2. Why do we need to act? What should we do? How should we do it? By when?

The generic form of roadmap illustrated in Fig. 1 highlights the flexibility of the approach, which can be readily adapted to suit a wide range of goals and contexts. In essence, roadmaps are simple, adaptable 'strategic lenses' through which the evolution of complex systems can be viewed, supporting dialogue and communication.

The use of the term 'roadmap' in the context of strategic planning has been traced back to the 1940s, although Motorola is generally acknowledged as playing a key role in popularising 'technology roadmapping' as a mechanism to support integrated product-technology strategy and planning (by improving alignment between technology and product development) in the late 1970s/early 1980s. Since then the approach has been adopted (and adapted) by many different organisations, at company[1], sector and national levels, to support many different strategic and policy goals – see Fig. 2. The underlying concept is very flexible, and roadmapping methods have been adapted to suit many different goals, supporting innovation, strategy and policy development and deployment.

A key break-through in the wider adoption of roadmapping was a collaboration in the semi-conductor sector in the early 1990s, initially in the USA, and then internationally, to develop the International Technology Roadmap for Semiconductors (ITRS). The difference with this type of roadmap is there is a desire to disseminate it widely, to influence standards and research investment policy. Unlike company roadmaps the International Technology Roadmap for Semiconductors is in the public domain[2], leading to a much wider aware-

1 Company-level roadmaps tend to be highly confidential, although specific parts, or sanitised versions may be shown for specific purposes, such as marketing or supplier communication. However, organisations have generally been open about the process of roadmapping. Since its inception in Motorola, the modern form of roadmapping spread to other large technology-intensive organisations, principally in the electronics, aerospace and defence sectors.

2 www.itrs.net

ness of the approach. Since then, notably stimulated by the US Department of Energy and Industry Canada, the approach has spread world-wide, and has become one of the most extensively used techniques for supporting strategic planning and innovation.

A recent survey of public-domain roadmaps has identified more than 900 examples from a wide range of sectors, including energy, transport, materials, aerospace, electronics, ICT, manufacturing, construction, healthcare, defence, and pure science. However, this widespread use has led to many different approaches for developing roadmaps, and many different representational formats, resulting in a confusing picture of the status of roadmapping as a management technique. The concept and term 'roadmap' was further popularised e.g. by the publication and promotion of the 'Roadmap for peace in the Middle East', although this has led to a proliferation of so-called 'roadmaps' that do not build on the intellectual origins of the approach.

3.2 Visual Presentation

Roadmaps can be considered as 'strategic lenses' through which complex systems (such as businesses or sectors) can be viewed (see Fig. 3). The purpose of this lens is to structure and represent multiple interrelated perspectives of the evolution of complex systems, providing a framework to support understanding and dialogue. The roadmap lens can be thought of as comprising two distinct layers:

1. An underlying information structure (how the information contained within the roadmap is organised);
2. An overlaying graphical/artistic layer, to (hopefully) improve the presentation of the information contained in the roadmap. This is a complex area, and in some cases the result may be to confuse the message;

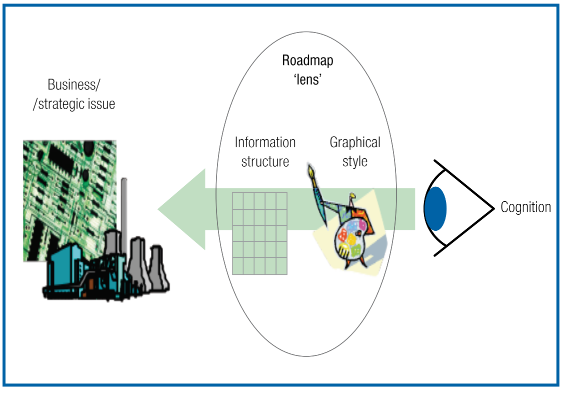

Fig. 3: Roadmaps as strategic lenses

Based on an analysis of more than 400 visual roadmap representations, a typology has been proposed for the underlying information structure layer described above, where fairly simple structures are apparent. An overview of the proposed typology is shown in Fig. 4 and Table 1. The typology is relatively simple, with only three major types of roadmaps identified, with five sub-types for the first (although hybrid forms do exist).

<table>
<tr><th>Type</th><th>Sub-type</th><th colspan="3">%</th></tr>
<tr><td rowspan="5">1) Temporal</td><td>1a) Single theme/sequential/linear</td><td>13,2</td><td rowspan="2">25,9</td><td rowspan="5">80,8</td></tr>
<tr><td>1b) Graph/quantified</td><td>12,7</td></tr>
<tr><td>1c) Single theme/sequential/branched</td><td colspan="2">7,2</td></tr>
<tr><td>1d) Multiple separate themes; sequential/linear/branched</td><td>36,7</td><td rowspan="2">48,4</td></tr>
<tr><td>1e) Multiple separate themes; sequential/linear/branched</td><td>11,7</td></tr>
<tr><td rowspan="2">2) System/process</td><td>2a) System (structure, components, relationships)</td><td>5,0</td><td colspan="2" rowspan="2">16,7</td></tr>
<tr><td>2b) Process</td><td>11,7</td></tr>
<tr><td>3) Metaphor</td><td>Roads, landscape, board game, funnel, etc.</td><td colspan="3">2,5</td></tr>
</table>

Table 1: Roadmap typology, based on information structure, indicating percentage of each type in collection

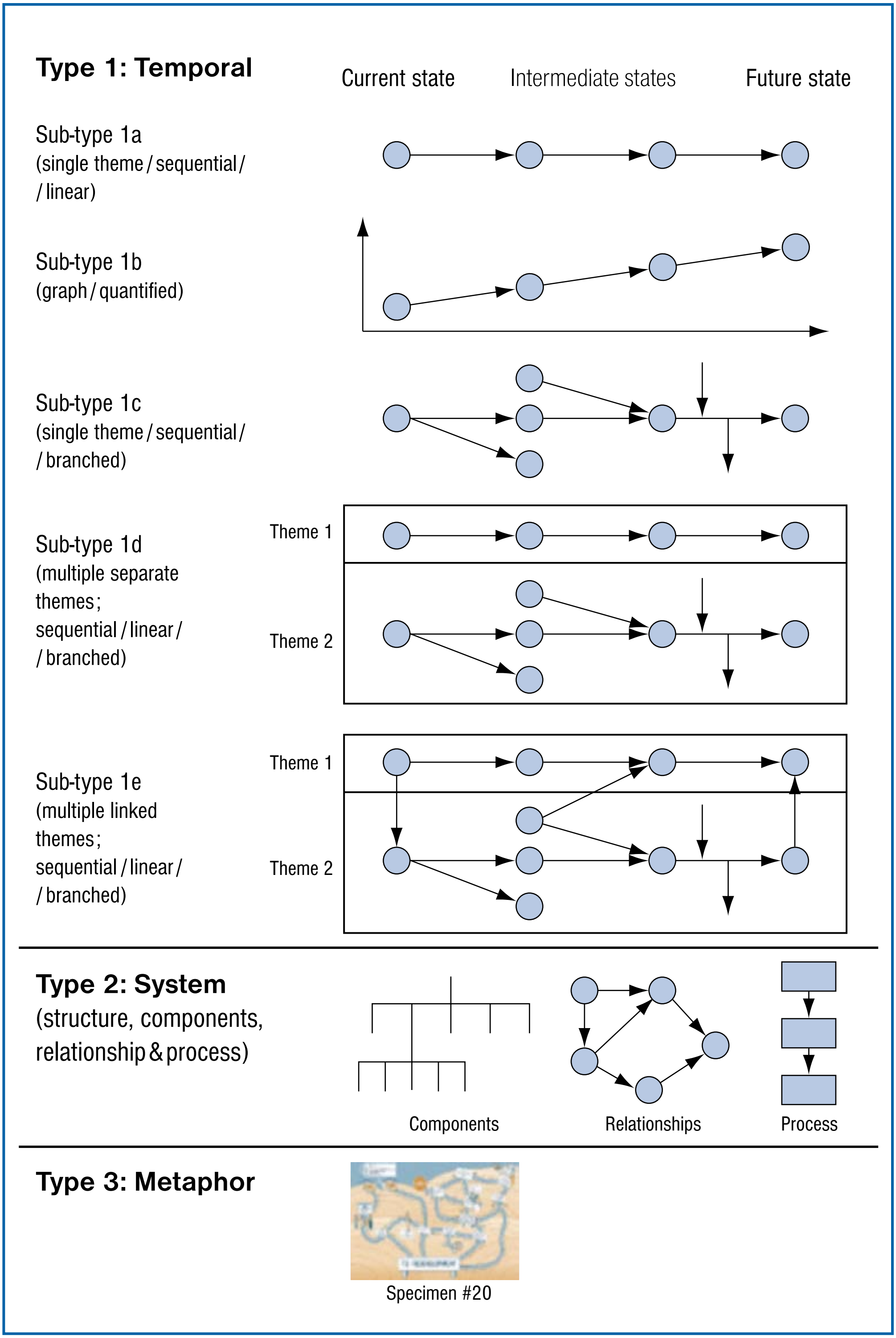

Fig. 4: Graphical roadmap typology (information structure)

The graphical/artistic layer is important, as the use of appropriate graphical devices and styles can both help and hinder understanding and communication. However, the situation here appears more challenging to interpret, as the range of graphical formats represented in the collection is large. It is believed that this is one of the main reasons why the variety of roadmaps forms is so apparently large, leading to some of the confusion about what roadmaps are and how they are structured, and making it difficult to identify patterns in their form. While examples of the graphical layer are presented, these aspects are not covered in any detail in this paper; nor does it consider the context or cognitive aspects of the model illustrated in Fig. 3. Further work will be required to address these aspects, building on theoretical and conceptual foundations.

Roadmaps can be organized into groups to create the 'dendrograms' shown in Fig. 5 (full-size figures of the dendrograms are shown in Chapter 4.4), which can be used as decision trees to support the design of roadmap visualisations:

1. **Purpose of roadmap.** Whilst the generalised roadmap framework shown in Fig. 1 provides the most effective structure for developing a comprehensive understanding of the evolution and strategy for complex systems, it may not be the most effective format for communication purposes. It is important to reflect on what the purpose of the roadmap is, who the audience is, and what the key messages are, which can help to identify the most appropriate visual format.
2. **Good visual structure.** The overall visual structure of the roadmap needs to be determined, to suit the purpose.
3. **Design pitfalls.** Once the purpose has been clearly defined, and overall visual structure determined, then the roadmap visualisation needs to be designed, avoiding visual pitfalls that might obscure the key messages that the roadmap is intended to communicate.

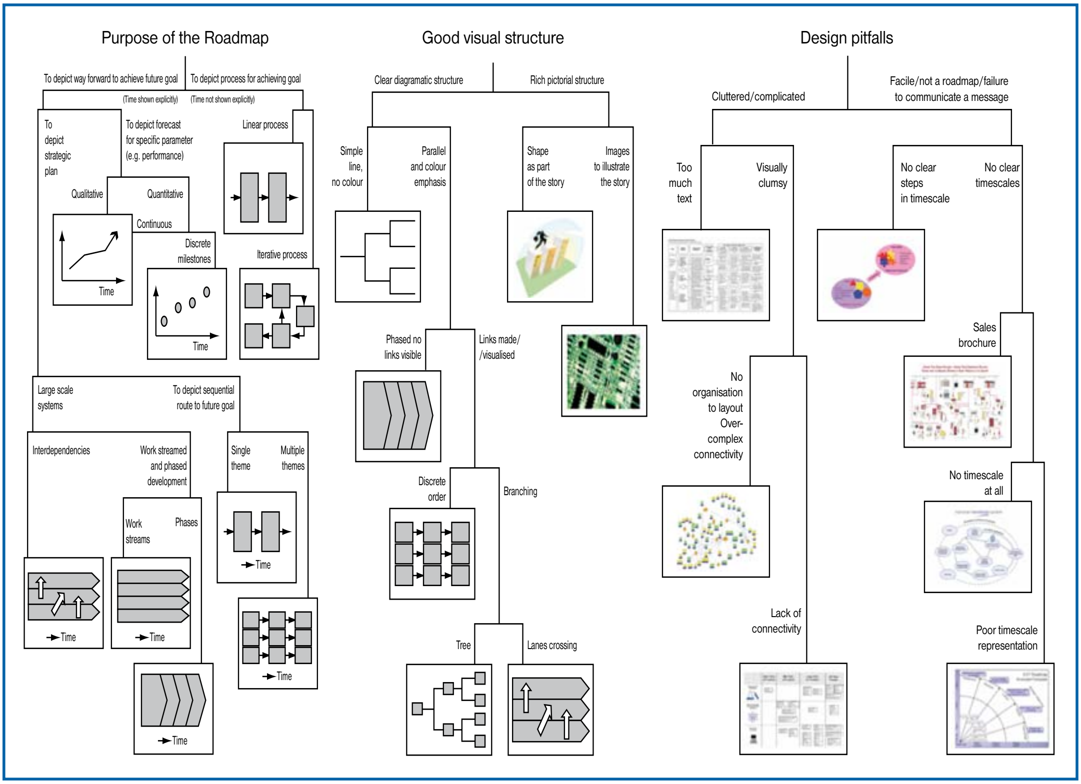

Fig. 5: Graphical roadmap representations – purpose, good visual structure and design pitfalls

3.3 Roadmap Implementation

3.3.1 Planning for Roadmapping

The key areas to consider when planning a roadmapping activity are:

- **Context** – the nature of the issue that triggered interest in roadmapping needs to be explored, together with any constraints that will affect the approach adopted. Careful consideration should be given to establishing a clear business need and ownership, defining aims and scope, and identifying key people from across the organisation that should be involved.
- **Architecture** – the layout of the roadmap needs to be designed (see Fig. 1), considering both timeframe and structure, comprising the layers and sub-layers. The roadmap can be considered as a 'dynamic systems framework', providing a structure within which the evolution of the system of interest can be mapped. Generally, this system relates to innovation, at the firm or sector level, where there is a need to align markets ('know-why') with applications & processes ('know-what'), and technology & resources ('know-how'), over time ('know-when'). The roadmap framework provides a 'common language', which supports communication between different communities (e.g. functions, technical disciplines or organisations).
- **Process** – this comprises the staged set of activities needed to build roadmap content, make decisions, identify and agree actions and maintain the roadmap that is developed. Typically the process will involve one or more workshops, for which the agenda needs to be designed to incorporate a logical set of facilitated activities, which can be combined in a flexible way to address the issues of interest.

It is important to consider at the planning stage how roadmapping can support core business processes in the organisation (in particular strategic planning, innovation and new product development). Success is more likely if roadmapping concepts and methods can be aligned to support these processes, rather than implemented as a separate approach. Roadmapping can support these processes at all stages, although the way in which it is used will differ. Figure 6 shows a typical innovation or strategy process 'funnel'. The roadmap provides a consistent framework throughout the process (a 'common language'), with the content of the roadmap evolving to ensure that the best current thinking is articulated and communicated at each stage.

While the multi-layer format illustrated in Fig. 1 is the most powerful and flexible method for developing roadmap, based on systems thinking, other graphical representations may be more appropriate for communicating the outputs to different stakeholder groups (for example, senior management, research teams, investors and suppliers).

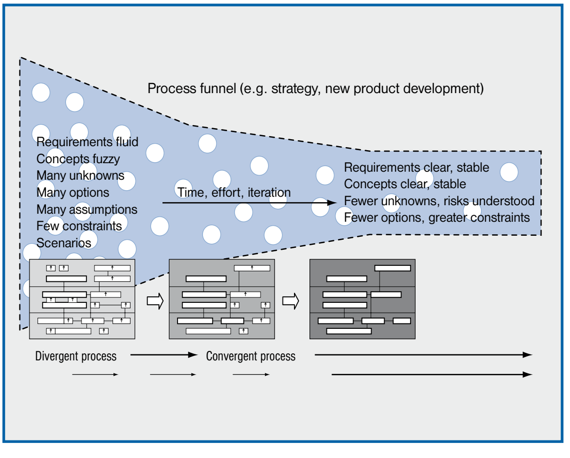

Fig. 6: Process funnel – at the front-end to support identification and exploration of opportunities, and later on to develop and implement strategic plans

3.3.2 Roadmapping Success Factors

In 2003, a study of the effectiveness of 'supra-company' (network level) roadmapping initiatives around the world was conducted, with the aim of assessing how roadmapping can support national innovation policy and systems. The study reviewed a total of 78 roadmapping initiatives, mainly in Europe, USA, Canada and Japan, from which the following 'good practices and lessons' were identified, which also apply to firm-level applications:

Planning:

- The roadmapping initiative should be clearly linked to broader strategy initiatives (for example, national innovation priorities).
- It is much easier to launch a roadmapping activity within an existing 'social infrastructure' (for example, an industry association).
- In order to mobilise participants there must be a sense of 'urgency'.
- Creating high-level commitment from the start is critical, involving decision makers within companies (and government) throughout the process.
- Visioning and goal setting is important, as a focus for developing consensus within the community.
- Industry oriented roadmapping activities should be owned by industry from the outset to encourage take--up.
- A clear link to decision-makers is important if roadmapping is to have impact.

Implementation:

- No single format is suitable for all situations – the approach generally has to be customised.
- It is important that momentum is sustained, to keep participants interested and involved.
- Roadmapping is inherently exploratory in nature, and so the plan should be flexible to accommodate learning as the process advances.
- A spirit of openness is important, to encourage new participants and thinking throughout the process.
- The financial aspects need to be clear – generally the costs of such initiatives are shared between the administrating and participating organisations.

Follow-up:

- Roadmapping is typically an iterative process, benefiting from review after the first roadmap is produced.
- Outcomes should be monitored, including uptake and impact.

3.4 T-Plan and S-Plan fast-start workshop approaches

3.4.1 The role of workshops

It is often claimed that the process of developing roadmaps is as important as the roadmaps themselves, due to the associated communication and network-building benefits. The process needs to be customised to suit the context, along with the structure and format of the roadmap. Consideration should be given to how the first roadmap is developed and then also to how the roadmap can be maintained, to provide an ongoing reference point for communities of interest. Typically, for substantial sector level roadmaps it might take several months or more for a first good quality roadmap to be developed (suitable for publication).

While the particular approaches vary considerably, the use of workshops as a key ingredient is a common feature, owing to the communication and network-development benefits, building consensus about what the key issues of interest and concern are, and the actions that are needed to move forward.

3.4.2 T-Plan and S-Plan fast-start workshop methods

The University of Cambridge Centre for Technology Management has been developing facilitated workshop--based approaches for supporting the initiation of roadmapping processes since 1998, involving more than 120 collaborations with a wide range of organisation types and sectors. The two approaches are summarised below, each based on cross-functional participation.

1. **T-Plan:** focusing on integrated product-technology planning (system level roadmapping), this process brings together 8–12 participants from across the organisation to develop a draft roadmap for a product (or product family), in four half-day workshops:

Fig. 7: Typical roadmapping workshop, showing how the roadmap framework provides a structured framework for guiding discussion and capturing views

- Market: external market and internal business drivers are identified, categorised and prioritised, and business strategy is reviewed.
- Product: potential product features, functions and attributes are identified and prioritised with respect to how strongly they address the drivers.
- Technology: potential technological solutions for developing the product features are identified and prioritised.
- Charting: based on the outputs from the first three workshops, the initial roadmap is developed, linking market, product and technology perspectives.

2. **S-Plan:** focusing on the 'fuzzy front end' of the strategy and innovation processes (see Fig. 6), at the organisation or network level, this process brings together 15–25 participants from across the organisation to identify and explore strategic options and opportunities for innovation, in a single workshop (see Fig. 7):

- Strategic landscape: considering the full scope of the business, the roadmap framework is used to share and capture perspectives from across the group of participants, identifying and prioritising strategic issues for discussion.
- Opportunity identification: drawing on the information in the strategic landscape, strategic options and opportunities for innovation are identified and prioritised.
- Opportunity exploration: in small groups, the roadmap framework is used to articulate the nature of the opportunity, map how it can be achieved, and identify key enablers and barriers.
- Review: participants agree which opportunities to take forward, and how to do so (typically feeding into company innovation and strategy processes).

Further work is typically required before, between and after workshops to collect data, analyse results, develop roadmap representations and associated reports, and to ensure that actions are taken forward.

3.5 Conclusions

Many organisations face fundamental challenges relating to scale, complexity, change and uncertainty. It is for these reasons that roadmapping is used widely in industry and government, providing a common visual framework and language to support dialogue and communication between the many people and groups that have to cooperate to achieve organisational goals.

Without roadmapping (or other effective integrating approach), these challenges can lead to a range of difficulties:

- Misalignment between different groups, functions and levels within the organisation (and with customers, suppliers and partners)
- Wasted resources and effort, and missed opportunities
- Late (or early) to market
- Increased risk (and lack of awareness of risk)
- Failure to exploit synergies within the business

Roadmapping is a powerful and flexible technique that is being increasingly adopted as a core integrating mechanism for strategic planning and innovation. A principle benefit is the communication that is engendered, both during the development of the roadmap and afterwards, using roadmaps as a common reference point and language to support the ongoing dialogue that is essential for effective innovation and strategy development and implementation. The 'hands-on' nature of the workshop-based process is a key feature, where the group is responsible for building a common visual representation of their strategic context, issues, goals and plans.

However, roadmapping can be challenging, due to a combination of the broad scope and complexity of the issues being addressed, uncertainties associated with the future, and gaps in available knowledge. The following success factors should be considered when embarking on a roadmapping initiative:

- Establish a clear need
- Ensure commitment from senior management and stakeholders
- Plan carefully and customise the approach to suit the circumstances
- Phase the process to ensure that benefits are delivered early
- Ensure that the right people, functions and organisations are involved
- Link the roadmapping activity to other management processes and tools
- Provide adequate support and resources
- Keep it simple
- Iterate and learn from experience

Finally, the test of whether a roadmap is 'good' is not the accuracy of prediction, which will always be subject to uncertainty and ambiguity, but whether it helps to develop understanding, communication and consensus about the way forward. A healthy roadmap should be dynamic and updated on a regular basis, or as the situation changes.

4. Steps for Developing Roadmaps

Step 1: Strategic Landscape

This activity is based on the S-Plan 'fast-start' workshop roadmapping approach, used in the first half of the process to:

- Share and capture participant perspectives, across the full scope of the area of interest.
- Prioritise and link key topics for more in-depth exploration.

Fig. 8: Typical Strategic Landscape workshop activity

For these steps, the aim is to identify and prioritise key strategic opportunities and challenges for developing nations, which will be used as the starting point for the subsequent activity.

The strategic landscape brainstorming activity focuses on a large roadmap wall chart, with participants using sticky notes to capture their views – see Fig. 8.

The landscape is populated progressively, layer--by-layer (see Fig. 9), prioritising issues and capturing linkages between the layers, after which key opportunities and challenges are identified and prioritised:

1. Trends & drivers
2. Application areas
3. Technology, science and resources

Recommended is the use of the roadmap poster to brainstorm perspectives layer-by-layer – see Fig. 9 and 10 (using sticky notes), including linkages:

1. Trends and drivers (national and global) – social, economic, environmental and political.
2. Products, services, applications and systems required from industrial sectors to respond to the trends and drivers.
3. Technology developments, actions and competences needed to deliver industrial products, services and systems, together with key scientific advances and resources required.

The following key questions to stimulate the brainstorm should be asked:

1) Industry trends and drivers (national & global): 'S(T)EEP' – social, (technological), economic, environmental and political
   - What external factors will affect society and industry in the future? What will future customer needs be? What future legislation is planned or likely?
2) Products, services, applications and systems required from industrial sectors to respond to the trends and drivers
   - What types of products, services, applications and systems will we require in the future? What performance and functionality will be required in the short, medium and long term?
3) Technology developments, actions and competences needed to deliver, industrial products, services and systems
   - How do you think technology will evolve to meet future requirements? What technologies are likely to develop or emerge in the short, medium and long term?
4) Underpinning science: What scientific advances might be expected over the next 20 years? Where should scientific research focus in the future?
5) Resources: What else will be important in the future? (e.g. skills, finance, alliances, infrastructure).

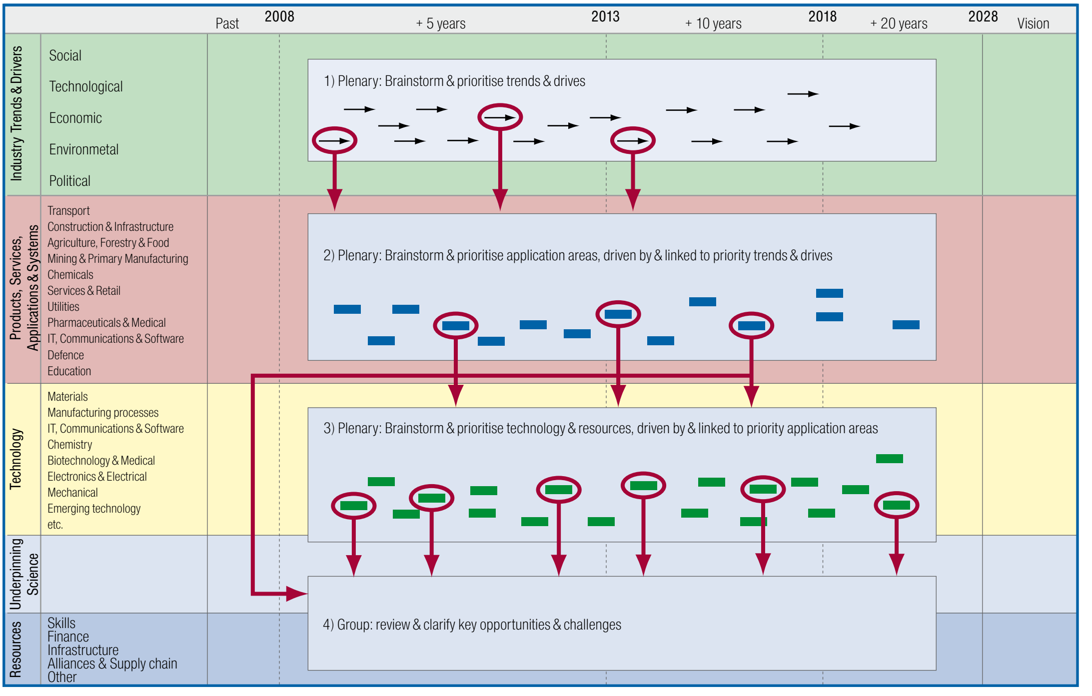

Fig. 9: Strategic Landscape activity stages

By using 'sticker vote', you identify and prioritise key opportunities and challenges for developing nations. In the next step, review priority opportunities and challenges, capturing discussion on flip chart for feedback:

- Description of opportunity/challenge
- Key market-application-technology linkages
- Key contributing factors/issues

Also, consider roadmap process learning points for discussion.

Step 2: Opportunity/Challenge Exploration

This activity is based on the S-Plan 'fast-start' workshop roadmapping approach, used in the second half of the process to:

- Explore and roadmap prioritised topics identified in Strategic Landscape activity.
- Identify key learning points and way forward.

For this exercise, the aim is to explore key strategic opportunities and challenges for developing nations, which will be used as the starting point for Step 3.

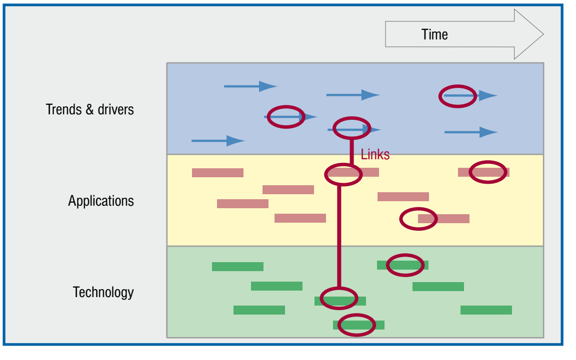

Fig. 10: Brainstorming and linking layers of the roadmap

A roadmap chart is used to explore topics of interest (Fig. 11), using sticky note to capture relevant trends and drivers agreeing vision and goals, and mapping potential route/s forward, in order to learn more about the topic (e.g. enablers, barriers, risks, decision points and gaps).

There should be a person nominated, who will have to steer the group discussion and present the roadmap 'narrative' during the feedback session.

The following broad steps generally used for trends identification (see Fig. 12):

1. Discuss the topic within the group so that the nature of the topic is understood by all (content, focus & scope), including consideration of key trends and drivers that influence the topic, together with any assumptions and constraints that apply. Agree the 'strategy' or approach that will be adopted for tackling the topic (for example, in a previous case two main exploitation routes could have been identified – incremental & radical; the group focused on the incremental route for the activity).
2. Discuss appropriate roadmap framework (broad layers & timeframes) for the topic, and sketch this on a flip chart sheet.
3. Determine the outcomes that could be expected if the opportunity is exploited (or challenge is addressed) successfully... a 'stake in the ground' (quantify, qualify, estimate or 'guesstimate' if possible – even order of magnitude is helpful). Consider short-, medium- and long-term benefits/goals (e.g. 1, 3 and 10 year timeframes). Remember, the top layer of the roadmap focuses on 'know-why' (purpose & goals – Fig. 1), and the influences that affect that purpose (trends & drivers).
4. Determine the required application (product, service, system) developments associated with the outcomes, together with any manufacturing process and operational system developments associated with the product and service evolution. Remember that the middle layer of the roadmap focuses on 'know-what' (performance, features, functionality) – the tangible cash generating parts of the business.
5. Determine the required technology/science/capabilities associated with the system development. Remember that this layer of the roadmap focuses on the 'know-how' ('hard' & 'soft' technology). Consider any additional resources or actions required to support the strategic plan, such as capital, skills, suppliers, organisation, etc.

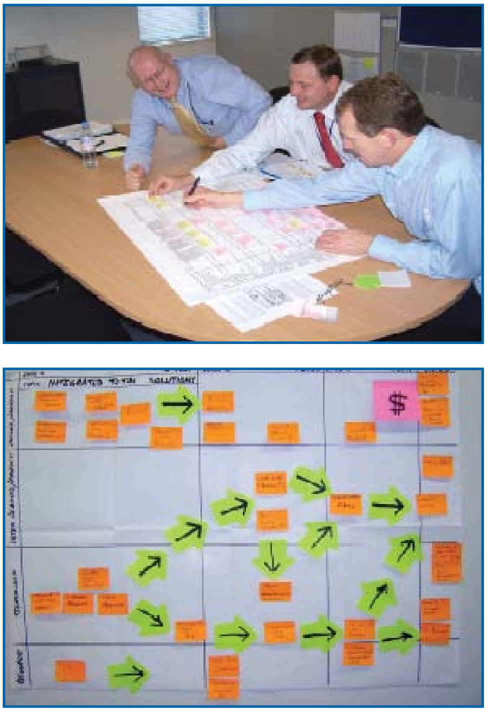

Fig. 11: Typical Topic Roadmap workshop activity and output

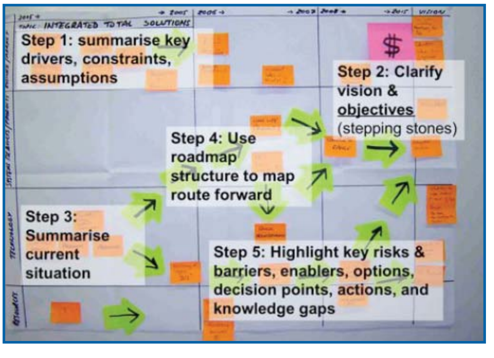

Fig. 12: Topic Roadmap process steps

6. Review the roadmap. Make sure that linkages are shown, and information is clear and where possible quantified (even if estimates or assumptions are required).
7. Identify key learning points for summary on separate flip chart sheet (opportunity/challenge, vision & objectives, enablers & barriers, risks, decision points, key actions, and knowledge gaps).
8. Prepare a short summary (10 minutes), summarising key points.
9. Review risks & barriers, enablers, options, decision points, actions, knowledge gaps.
10. Identify roadmap process learning points.

Step 3: Planning for Roadmapping

The roadmapping process generally needs to be customised to address the particular topic of interest, which requires that appropriate attention is given to the design stage, to manage the risks of what can be a high--profile initiative.

The aims of this step is to review the topic roadmap produced in Step 2, and identify the key risks that should be managed if you were to implement a roadmapping initiative for your opportunity/challenge.

The topic of the roadmap should be reviewed in light of the following frameworks (Fig. 13–16) to identify and prioritise project risks on flip charts (to feedback the top 3). This is valid also for Fig 15, as the general planning of such kind should be done at the beginning of the roadmapping process. At this stage of the process, it serves as a review tool.

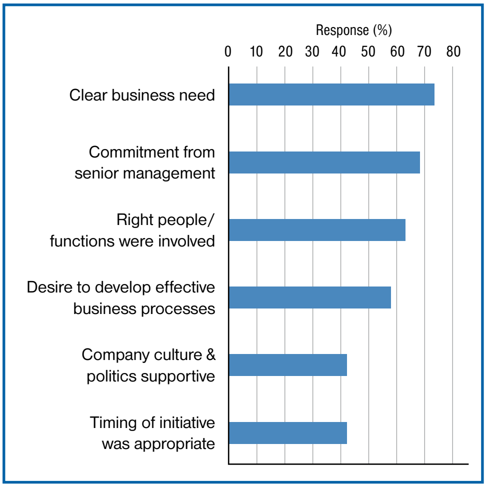

Fig. 13: Top six roadmapping success factors

Source: CTM survey, 1999

Step 4: Developing a Strategic Narrative

The main benefit of roadmapping is communication, both during the development of the roadmap (the roadmapping process) and subsequently (dissemination of the roadmap). The visual format of the

Preparation:

- The need to link to broader policy strategy
- The benefit of launching the roadmapping initiative within an existing network ('social infrastructure')
- The importance of creating a 'sense of urgency'
- Ensuring high-level commitment
- The importance of 'visioning' and goal setting
- The need for active industrial development and ownership
- A clear link to decision makers

Implementation:

- There is no single format that works best (i.e. customisation is typically required)
- The need to sustain momentum, supported by a good process
- The need to maintain a degree of flexibility
- A culture of openness
- Consideration of resource issues, in terms of effort and finance

Follow-up:

- Iteration (reviewing the roadmap on regular basis)
- Monitoring putcomes, uptake and impacts

Fig. 14: Critical success factors in 'supra-company' level roadmapping initiatives

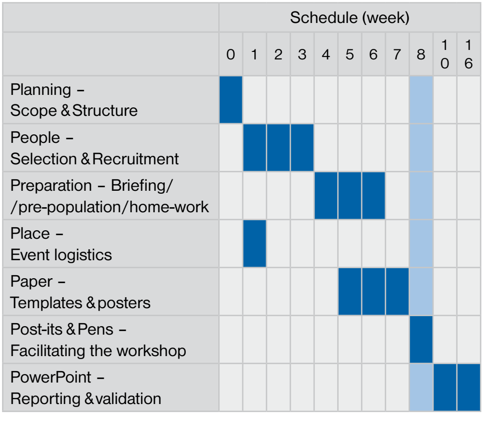

Fig. 15: Planning and delivering a roadmapping workshop (the 8 'P's)

- Context: focus, scope, aims and resources
- Roadmap architecture
- Process
- Participants
- Workshop schedulling
- Integration: systems, processes & information
- Preparatory work

Fig. 16: Planning (customisation) checklist for roadmapping

roadmap is important, which depends on the purpose, audience, intended message/s, together with the associated 'strategic narrative' (for example, the presentation that explains the roadmap, or the text that goes with the graphical roadmap in a business case, research proposal or foresight document).

The purpose of this activity is to build on the outputs from Steps 2 & 3, to consider aspects of roadmaps as aids to communication, and to revise and present the roadmap and associated strategic narrative.

Many visual roadmap formats have been developed, as illustrated in Fig. 17. While the multi-layered time-based view is the most generic and powerful format for roadmap development, different formats may be appropriate for communication of the key messages that emerge from the development of the roadmap. Using recent research outputs, supported by examples presented in the course, this activity provides an opportunity to consider what style of roadmap visualisation is appropriate for presenting the roadmap and the associated strategic narrative.

The next activities are to review the opportunity/challenge roadmap. To do it thoroughly, the following activities and questions should be done and answered:

1. Developing the 'strategic narrative' to present roadmap for feedback, using flipchart to capture key points (flip charts), using the following headings for guidance (there may be other factors you want to emphasise):
   - Title
   - Purpose
   - Drivers
   - Vision
   - Goals
   - Route forward
   - Risks/Issues
   - Actions
2. Who is the audience for the roadmap? What are the key messages?
3. Using the 'Purpose of the roadmap' decision tree (Fig. 18) to clarify the purpose.
4. Using the 'Good visual structure' decision tree (Fig. 19) to decide what overall format is most appropriate.
5. Reviewing the 'Design pitfalls' decision tree (Fig. 20) to clarify which visualisation choices might not be helpful for communication purposes.
6. Revision of the roadmap for feedback (simply? redraw?).
7. Considering key roadmap process learning points.

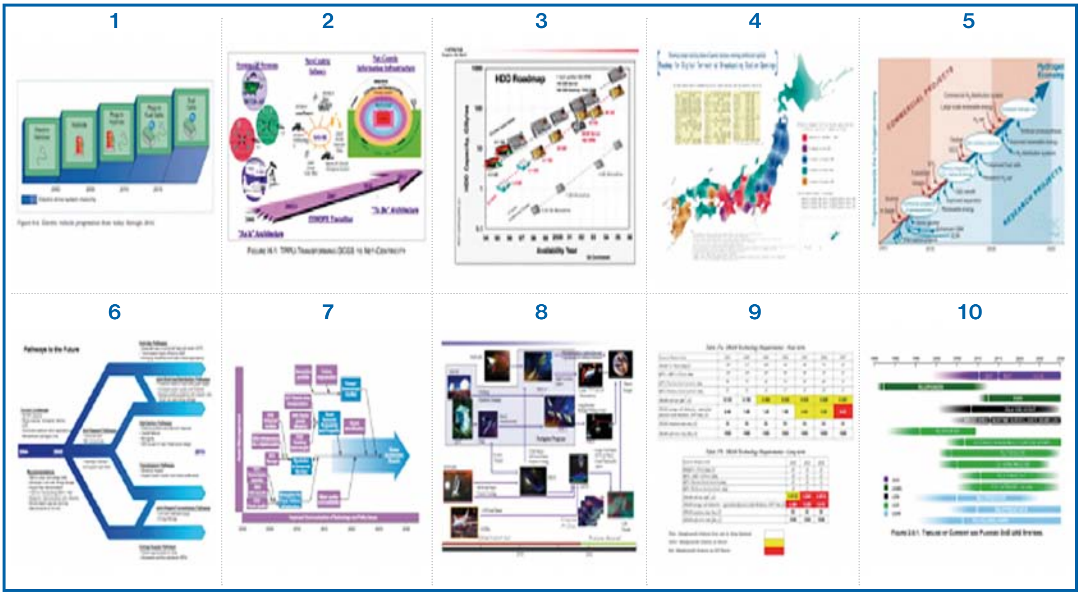

Fig. 17: A selection of visual roadmap formats

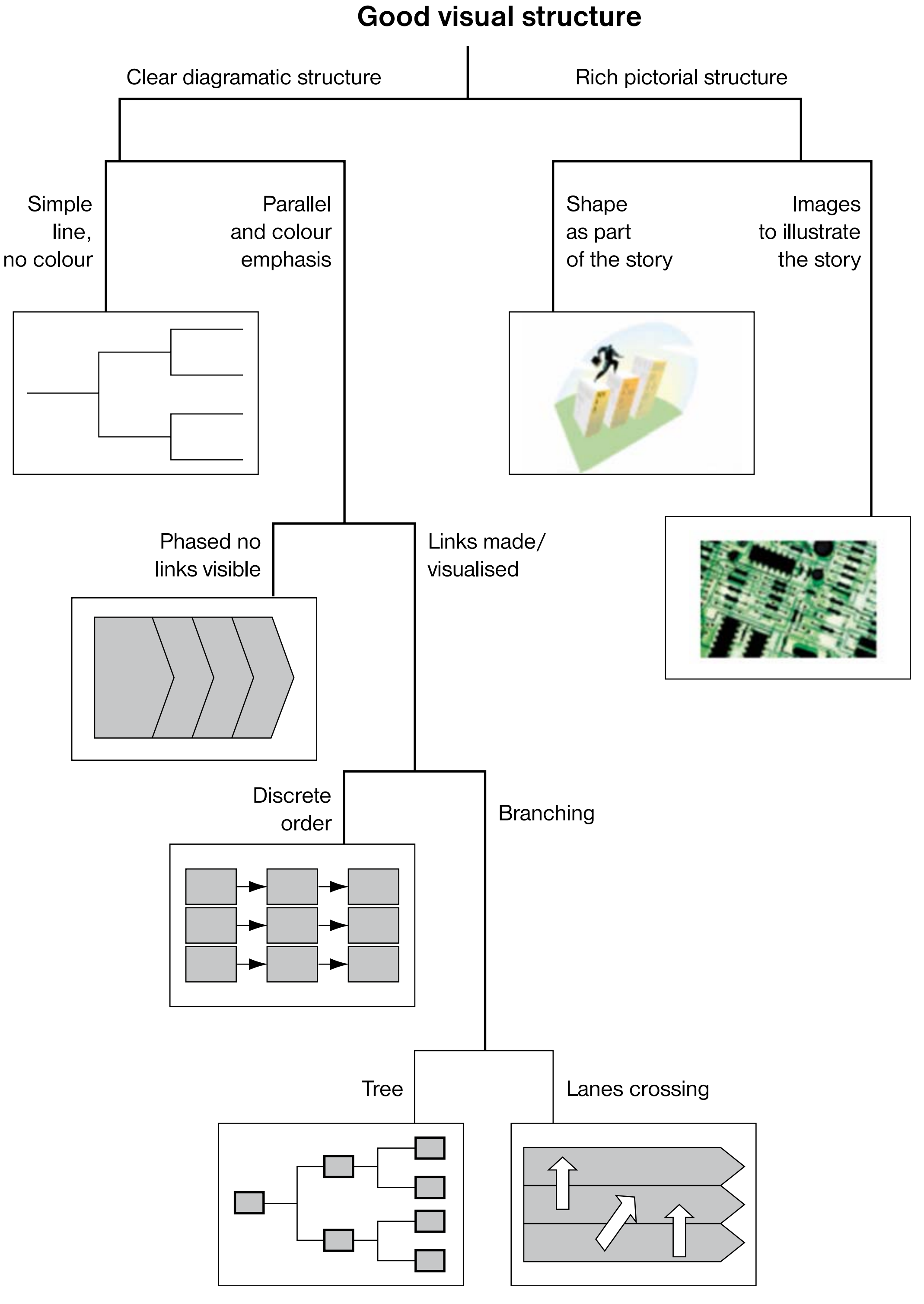

Fig. 18: 'Purpose of the roadmap' decision tree

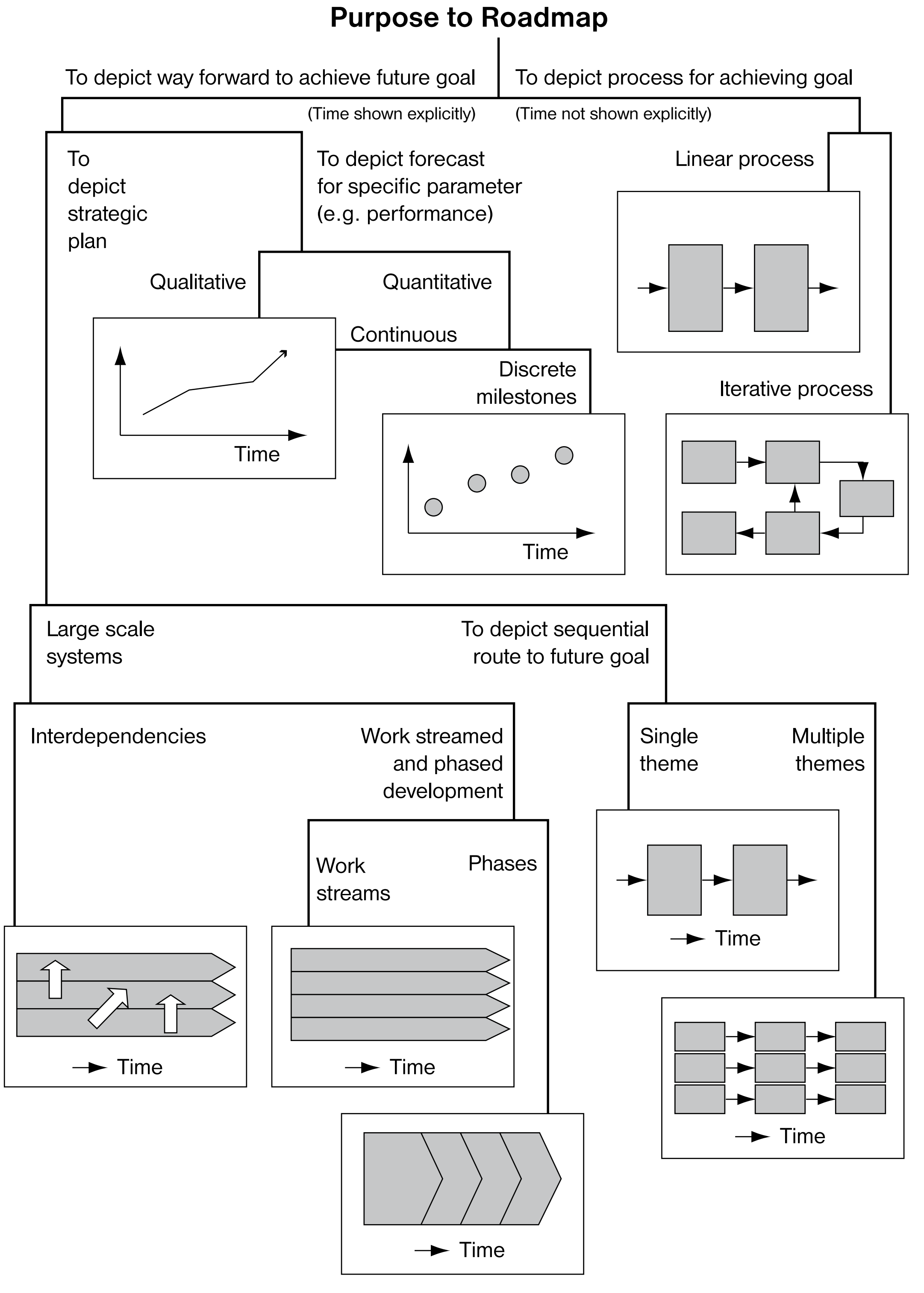

Fig. 19: 'Purpose of the roadmap' decision tree

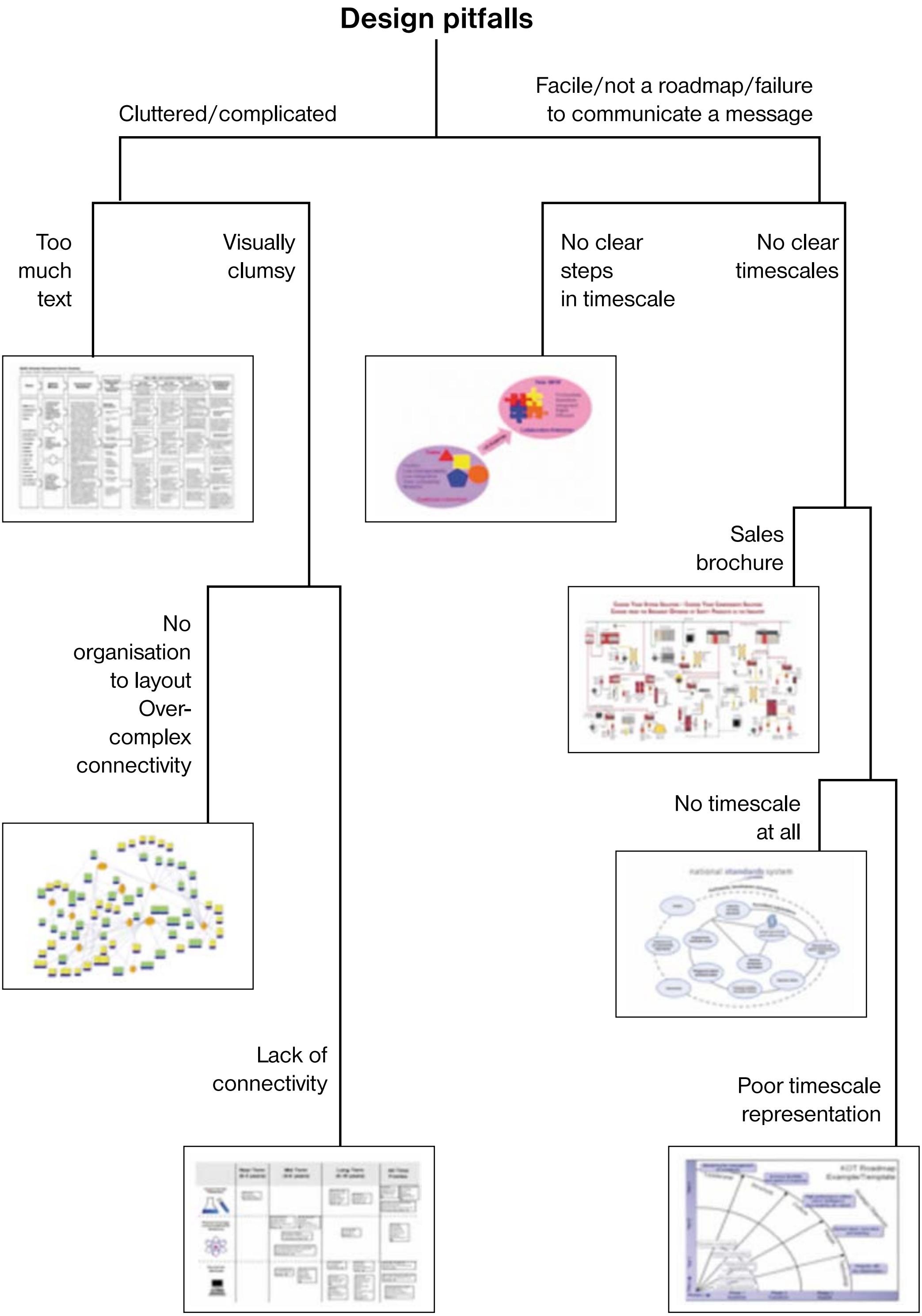

Fig. 20: 'Design pitfalls' decision tree

5. Bibliography

Chapter 2:

Georghiou, L., Cassingena Harper, J., Keenan, M., Miles, I., Popper, R. (Eds) (2008): The Handbook of Technology Foresight, Cheltenham, UK and Northampton, MA, USA: Edward Elgar.

Irvine, J., Martin, B. (1984): Foresight in Science: Picking the Winners, London: Pinter.

Martin, B. Irvine, J. (1989): Research Foresight, London: Pinter.

Keenan, M., Miles I., Jari Koi-Ova (2003): Handbook of Knowledge Society Foresight European Foundation, Dublin, available at *http://www.eurofound.eu.int/transversal/foresight.htm and http://mbs.ac.uk/PREST/euforia/documents/ EFL_Handbook_April_2003.pdf*

Miles, I., Keenan M. (Eds) (2003): Practical Guide to Regional Foresight in the United Kingdom (versions of this report are published in every EU15 country except Luxembourg,) Luxembourg, European Commission, EUR 20478, ISBN 92 894 4682 X; all versions online at: *http://cordis.europa.eu/foresight/cgrf.htm*

Miles, M.B., Huberman A. M., (1994): Qualitative data analysis: An expanded sourcebook (2nd ed.), Newbury Park, CA: Sage

Popper, R., Keenan, M., Miles, I., Butter, M., Sainz de la Fuenta, G. (2007): Global Foresight Outlook 2007, EFMN Network, available at *http://www.efmn.info/*

Popper, R., (2008): "Methodology". In Georghiou L., Cassingena Harper J., Keenan M., Miles I., Popper R. (Eds): The Handbook of Technology Foresight, Cheltenham, UK and Northampton, MA, USA: Edward Elgar.

Chapter 3 and 4:

Anderson, M., Meyer, B. and Oliver, P. (Eds) (2002): Diagrammatic representation and reasoning, Springer-Verlag.

Beeton, D. (2006): Exploratory roadmapping for foresight in the consumer packaging sector, PhD thesis (in preparation), University of Cambridge.

Crilly, N., Blackwell, A.F. and Clarkson, P.J. (2006): 'Graphic elicitation: using research diagrams as interview stimuli', Qualitative Research, 6 (3), pp. 341–366.

De Laat, B. and McKibbin, S. (2003): The effectiveness of technology road mapping – building a strategic vision, Dutch Ministry of Economic Affairs. [*www.ez.nl*]

Galvin, R. (1998): 'Science roadmaps', Science, 280 (5365/8), p. 803.

Lohse, G.L., Biolsi, K., Walker, N. and Rueter, H.H. (1994): 'A classification of visual representations', Communications of the ACM, 37 (12), pp. 36–49.

Phaal, R., Farrukh, C.J.P. and Probert, D.R. (2001): T-Plan: the fast-start to technology roadmapping – planning your route to success, ISBN 1-902546-09-1, Institute for Manufacturing, University of Cambridge.

Phaal, R., Farrukh, C.J.P. and Probert, D.R. (2001a): 'Characterisation of technology roadmaps: purpose and format', Proceedings of the Portland International Conference on Management of Engineering and Technology (PICMET '01), Portland, 29th July–2nd August, pp. 367–374.

Phaal, R., Farrukh, C.J.P. and Probert, D.R. (2004): 'Customizing roadmapping', Research-Technology Management, 47 (2), pp. 26–37.

Phaal, R., Farrukh, C.J.P. and Probert, D.R. (2005): 'Developing a technology roadmapping system', Portland International Conference on Management of Engineering and Technology (PICMET '05), Portland, 31st July–4th August.

Phaal, R., Farrukh, C.J.P. and Probert, D.R. (2007): 'Strategic roadmapping: a workshop-based approach for identifying and exploring innovation issues and opportunities', Engineering Management Journal, 19 (1), pp. 16–24.

Probert, D. and Radnor, M. (2003): 'Frontier experiences from industry-academia consortia', Research Technology Management, 42 (2), pp. 27–30.

Spence, R. (2001): Information visualization, Addison-Wesley.

United Nations (2001): A performance-based roadmap to a permanent two-State solution to the Israeli-Palestinian conflict.

Ware, C. (2004): Information visualisation – perception for design, 2nd ed., Amsterdam: Morgan Kaufmann / Elsevier.

Willyard, C.H. and McClees, C.W. (1987): 'Motorola's technology roadmapping process', Research Management, Sept.–Oct., pp. 13–19.

6. About the Authors

Robert Phaal

Robert Phaal joined the Centre for Technology Management at Cambridge University in 1997, and is currently engaged in a research programme to investigate strategic technology management issues in manufacturing organisations. The particular focus of the research is how to link technology resources to company objectives, in order to develop a set of practical and well-founded tools to support technology strategy and planning initiatives in the firm. A particular focus over the past 10 years has been the technology roadmapping approach, which has been applied at product, business, corporate and sector levels. Rob has a background in mechanical engineering, consulting and contract research, having previously worked for The Welding Institute for six years.

Ian Miles

Ian Miles was a Director of PREST (Policy Research in Engineering Science and Technology), and of CRIC (Centre for Research in Innovation and Competition) at the University of Manchester. These groups are now merged into MIoIR (Manchester Institute of Innovation Research), which still pursues work on service innovation, foresight, and related topics. Before moving to Manchester in 1990, he was for 18 years a researcher at SPRU (the Science Policy Research Unit) at the University of Sussex. Before this Ian received a first class honours BSc in Psychology at Manchester, and carried out research in social psychology. His research interests include innovation studies, foresight, indicators (social indicators and S&T data) and knowledge-intensive service sectors.

ANNEX 1: Case Studies

Four short case studies illustrate the application of the T-Plan and S-Plan fast-start workshop methods:

- Company level: product-technology planning in a medium-sized industrial printing manufacturer (T-Plan), and strategic planning in a large global packaging corporation (S-Plan).
- Sector (network) level: automotive research in the UK automotive sector, and national measurement priorities for emerging technology.

Printing – developing product-technology roadmaps

This case describes how a medium-sized company (1,500 employees) that develops and manufactures printing solutions for industrial applications implemented roadmapping over a period of several years.

The business is organised primarily around four business units, each focusing on a different product line, with some overlap in technology and markets. The company headquarters are in Europe, co-located with core design and manufacturing operations, with regional centres and sales and support organisations based around the world, in more than 150 countries. The company is 30 years old, and has a strong technology heritage. As the company has grown in size and complexity, new technologies have been acquired and the product range expanded, with a need to establish methods to manage the effective acquisition and integration of technology into the core new product introduction process.

Prioritization (P):	*7*	*3*	*0*	*2*	*6*	*5*	*1*	*8*	*10*	*8*	*9*	*5*	*(out of 10)*			
	Market								Company				*Score = ∑ ticks × P ✓ = 1 ✓✓ = 2 ✓✓✓ = 3 × = −1 (N) = normalized*			
Market/ Business Drivers / Product Feature Concepts	1. Market Driver 1	2. Market Driver 2	3. Market Driver 3	4. Market Driver 4	5. Market Driver 5	6. Market Driver 6	7. Market Driver 7	8. Market Driver 8	A. Business Driver 1	B. Business Driver 2	C. Business Driver 3	D. Business Driver 4	Score Market	(N)	Score Company	(N)
1. Feature Area 1	?						✓		✓✓			✓	*1*	***0***	*25*	***4***
2. Feature Area 2	✓✓						✓✓		✓	✓✓✓		✓	*16*	***4***	*39*	***6***
3. Feature Area 3		✓✓✓			✓				✓	✓✓	✓		*15*	***4***	*35*	***5***
4. Feature Area 4	?		✓✓✓			✓✓	✓✓	✓	✓✓✓	✓✓	×		*20*	***5***	*37*	***6***
5. Feature Area 5	?					✓✓✓	✓	✓✓✓	✓	✓	?		*40*	***10***	*18*	***3***
6. Feature Area 6	?	✓				✓	✓✓		✓	✓✓		✓	*16*	***4***	*31*	***5***
7. Feature Area 7	✓✓	✓		✓	✓	✓	✓✓		✓	✓	✓✓		*32*	***8***	*36*	***6***
8. Feature Area 8	×	✓✓		✓	✓		✓		✓	✓	×		*8*	***2***	*9*	***1***
9. Feature Area 9					✓✓✓	✓✓✓	✓✓		✓✓	✓✓	×		*35*	***9***	*27*	***4***
10. Feature Area 10	✓✓	✓✓							✓✓✓	✓	✓✓✓		*20*	***5***	*65*	***10***
11. Feature Area 11		✓	✓	✓	✓	✓✓	✓✓		✓✓	✓		✓	*23*	***6***	*33*	***5***
12. Feature Area 12	×	✓✓		✓	✓		✓✓		✓✓	✓✓	×		*9*	***2***	*27*	***4***
13. Feature Area 13	✓	✓✓	✓		✓✓	✓✓	✓✓		✓✓✓	✓✓✓		✓	*36*	***9***	*59*	***9***

Fig. 21: Cross-impact matrix, linking market and business drivers to product areas

As a technology-based company, the firm was particularly aware that developing new technologies (or other competences) could take a long time. The company had had experience of including new technologies in product development projects before they were fully tried and tested. The result had always been delay and disappointment.

To avoid this it was clear that they needed a coherent product-technology strategy so that innovations could be developed in advance and then brought to market quickly and securely when required, and roadmapping was selected as the most appropriate approach.

Roadmapping was first applied in the largest and oldest business unit, which is based on the mature continuous inkjet printing technology. The main outcomes of this application were the recognition that too many projects were being pursued, and that there was a lack of confidence that the market drivers were up-to-date. A market research study was undertaken, and the roadmap revised, and a series of new product initiatives followed. Based on this experience the method was rolled out to the other parts of the business.

Figure 21 illustrates the kind of cross-impact matrix that is used as a core part of the T-Plan method, in this case linking market and business drivers to product areas (functions and features). A second similar matrix is used to link these product areas to technology, providing a simple framework for understanding the relationships between the market, product and technology perspectives, supporting dialogue within the workshop.

Figure 22 shows an example of the first roadmap developed in one of the business units, forming the basis of an iterative process for reviewing and updating the roadmap on a regular basis. Figure 23 shows a more recent version of this roadmap, illustrating how the method evolved over a period of several years (Fig. 23a shows the underlying roadmap, with the feature and performance evolution overlaid in Fig. 23b).

The T-Plan 'fast-start' process was used in all business units in the firm, and proved an effective way to create initial roadmaps efficiently and quickly. In all cases the first roadmap showed that the existing plans

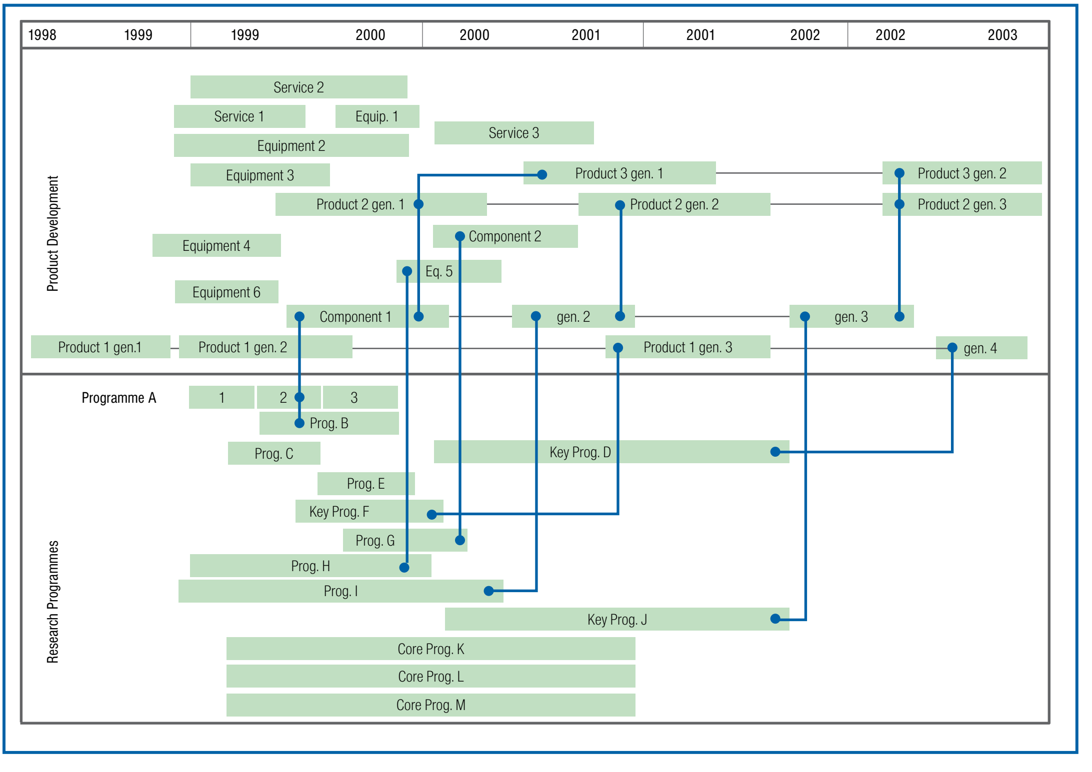

Fig. 22: Initial product-technology roadmap

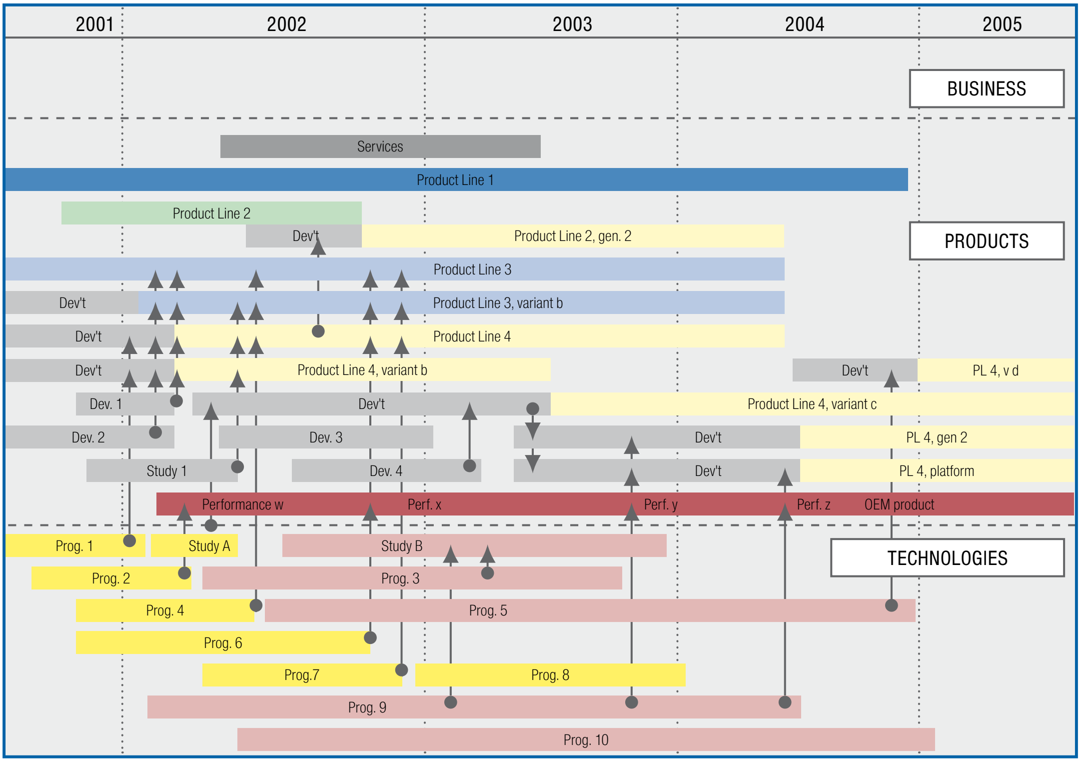

Fig. 23a: Mature product-technology roadmap (project view)

and intentions were too ambitious, and had to be scaled back – a valuable early result and a useful benefit from the work.

Nevertheless, managers and staff usually treated the first versions of the roadmaps with caution and only really trusted them after they had been through several iterations. These reviews, typically every six months, were crucial. They gave time for participants to gather extra data and to reflect on what had been done. Inevitably the maps evolved and stabilised with repeated discussion but the process of debate also cemented understanding and support.

The roadmaps became a useful and valued tool for communicating the emerging strategy to the board of the company and to others in the company. The next stage for the company will be to bring the business unit roadmaps together to expose the synergies between them that can lead to further efficiencies.

Packaging – aligning corporate research with business goals

This case focuses on a large global packaging company with a central European corporate R&D facility and business units distributed around the world, organised in terms of geography and product lines. The company had grown through a series of acquisitions, with the corporate R&D Centre a legacy from one of the original companies. The central research laboratory provided troubleshooting and development support, funded directly by business units on a project basis. In addition, a 'tax' was levied on the business units to fund longer-term research, focusing on new materials, products and processes.

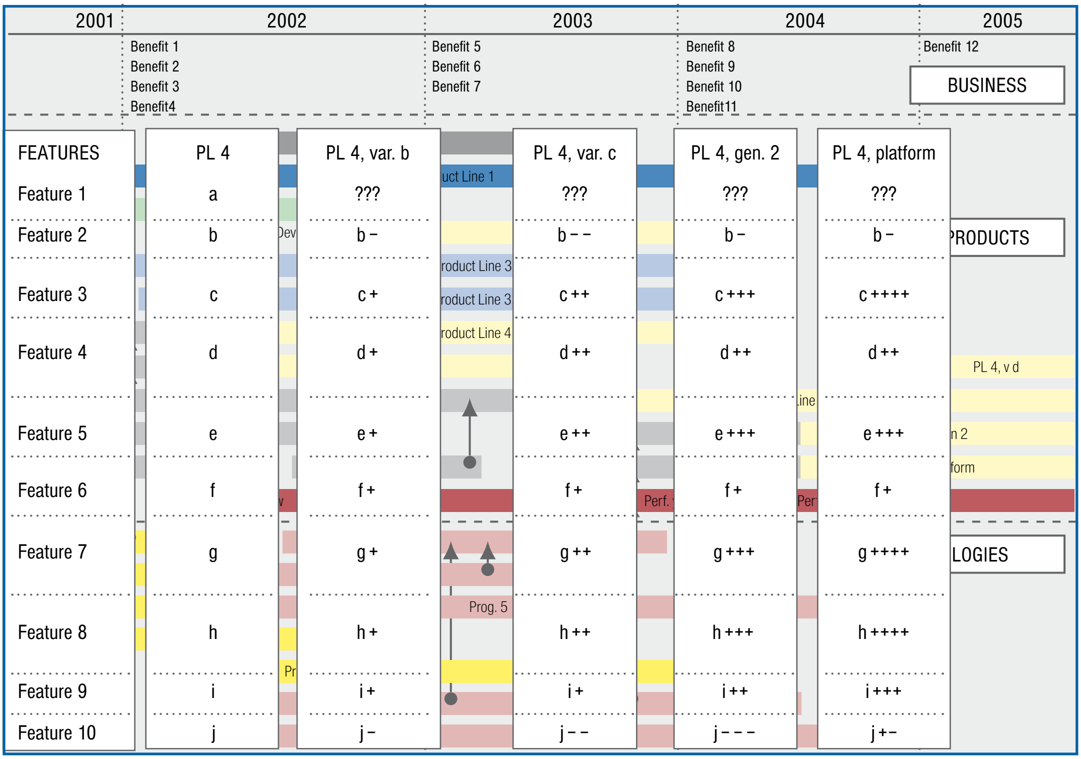

Fig. 23b: Mature product-technology roadmap (product feature/performance view)

A key challenge for the company was a lack of alignment between business unit goals, which tend to focus on the short- and medium-term, with investment in longer term R&D in the research laboratory. There was a history of interesting technology developments that were not deployed in the business units, leading to a concern that corporate research budgets would be cut substantially, and the central research laboratory potentially closed.

A series of 2-day workshops were held, each focusing on particular business units, bringing together staff from both organisations, with the commercial perspective provide by the business unit and the technological perspective by the corporate R&D centre. The process was piloted first in one business unit, and then applied across other key business areas.

In each case, three key people worked together to plan and run the workshop, and ensure that the outputs were taken forward, both within the business unit and the research laboratory, leading to a realignment of research programmes and a series of new product developments:

1. Senior manager within the central research laboratory, responsible for the interface with the business unit. This person tended to instigate the process, liaised with the business unit to ensure their commitment, made sure that appropriate technical experts participated in the workshop, and ensured that the outputs were implemented within the laboratory.
2. General Manager of the business unit, who ultimately 'owned' the resulting roadmaps that were generated in each workshop, which focused on innovation opportunities and strategic options for the business unit. This person ensured that the business objectives were clearly understood, made sure that appropriate commercial, development and managerial staff participated in the workshop, and ensured that the outputs were implemented within the business.

3. Facilitator, an expert in roadmapping techniques, who helped to design and coordinate the process, and facilitated the workshops. This role was initially undertaken by an external consultant, but one of the aims was to ensure that the learning was transferred to the company. After the first three workshops staff in the research laboratory took on this role.

The main outputs from each workshop were a prioritised set of innovation opportunities and strategic options for the business units, and agreed plans to take these forward, combined with an understanding of the technologies needed to support these plans. This included short-, medium- and long-term technical priorities, aligned with the troubleshooting, development and research activities in the laboratory. The priorities established during the roadmapping process were compared to the existing R&D portfolio. Where existing programmes were identified that matched the business unit priorities these were strengthened, and where gaps were identified budgets were reallocated (projects where there was no link to business needs were stopped).

The overall benefits of the process were:

- Reinvigorated innovation strategy in the business units, with new opportunities identified and pursued.
- A realigned corporate research budget, linked to the future business needs of the company.
- A much stronger relationship between business units and research laboratory, and improved pull through of technology into the business.

Automotive sector – research priorities and network development

The Foresight Vehicle programme[3] is administered by the UK Society of Motor Manufacturers and Traders (SMMT), with support from the DTI. The initiative has been running for more than ten years, providing a national focus for technology development within the automotive sector in the UK. More than 100 individual projects have been generated, covering a wide range of manufacturing processes and product concepts.

A major roadmapping initiative was undertaken in 2002 (see Fig. 24), with the aims of identifying the technology areas that would benefit from support (aligned with EPSRC funding) and building the network of organisations involved. The process for developing the first version of the roadmap involved a total of 10 workshops over a period of 10 months, involving more than 160 participants from 60 organisations (including industry, academia and government).

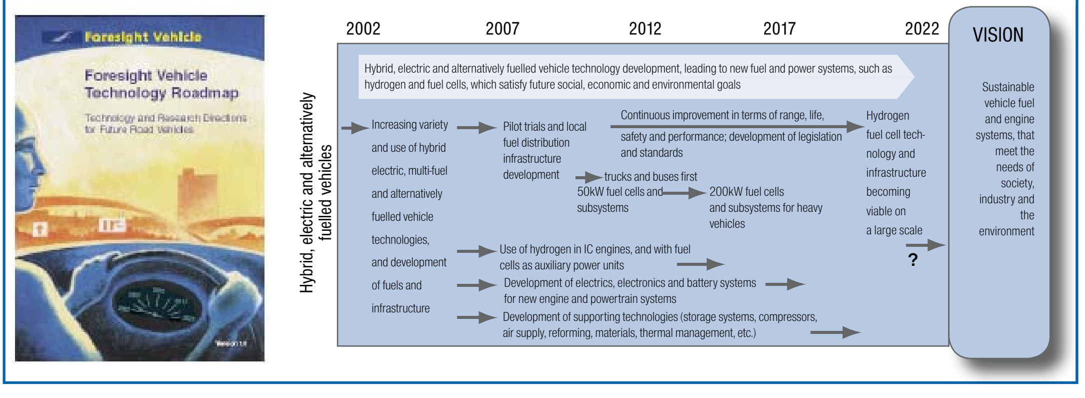

Fig. 24: Foresight Vehicle Technology Roadmap report (version 1), showing high-level roadmap for 'hybrid, electric and alternatively fuelled vehicles'

1 www.foresightvehicle.org.uk

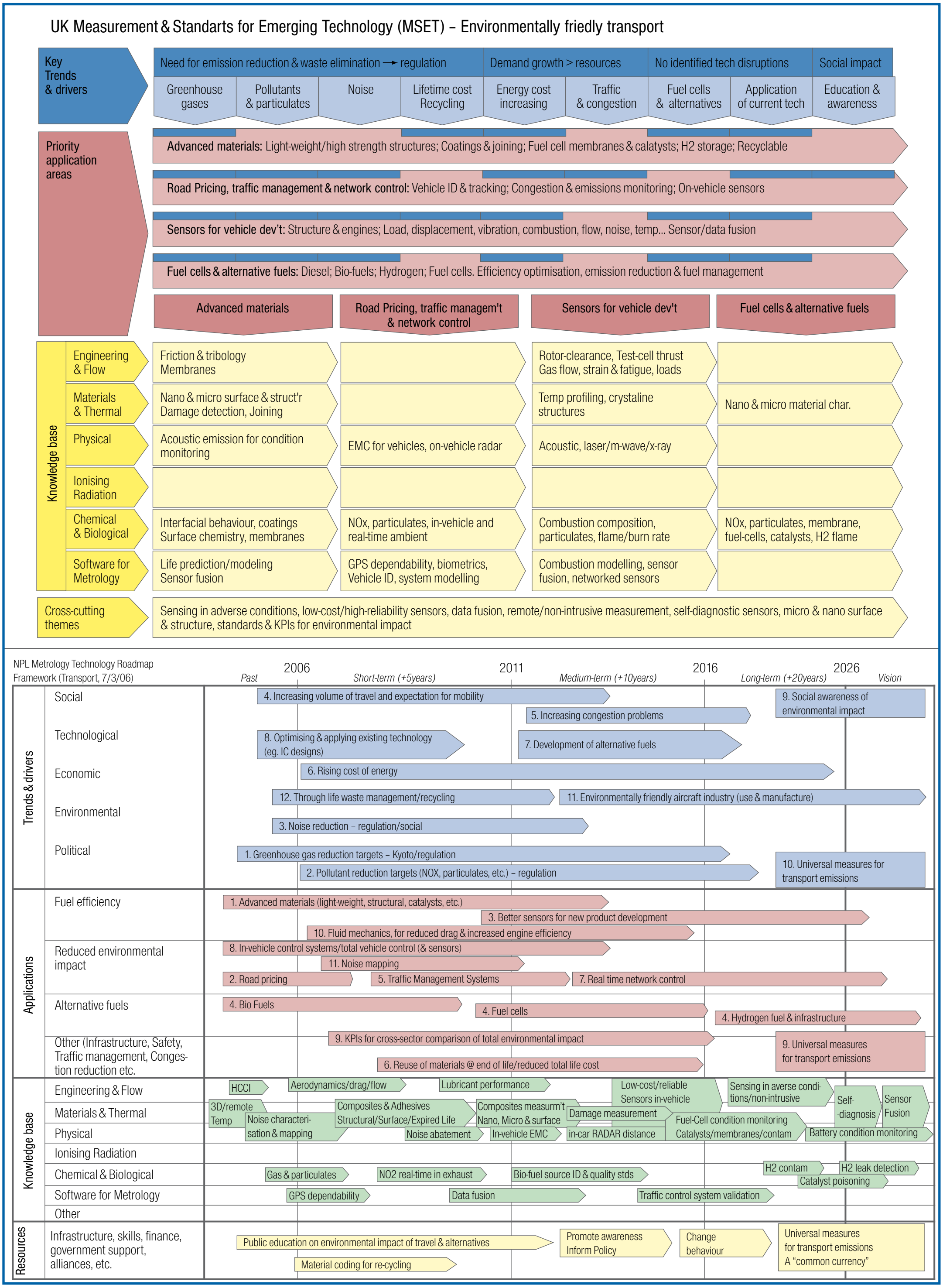

Fig. 25: Executive summary roadmaps for Environmentally friendly transport – a common structure throughout the eight sector roadmaps enabled crosscutting themes and synergies to be identified

The Foresight Vehicle Technology Roadmap has been widely disseminated, and has become a key reference point within the UK automotive sector, and internationally. The success of the first roadmap is demonstrated by the fact that the SMMT commissioned an update in 2004 (version 2), and is currently planning a third round.

Measurement science – national research priorities for emerging technology

The Measurement and Standards for Emerging Technologies (MSET) series of roadmaps[4] were developed in 2006 (see Fig. 25), to identify measurement technology needs and research themes in a number of key UK sectors. A series of one-day workshops were held, each relating to a different sector: Environmentally friendly transport, Secure environment, Sustainable consumption & production, Emerging energy technologies, Healthcare & bio-science, Intelligent connected world, Design, engineering & advanced manufacture, and the Built environment.

More than 100 non-NMS (National Measurement System) participants were directly involved in workshops, including industry (large and small companies), trade organisations, universities and the public sector (government departments and agencies, and research networks). Further consultation with the wider community enabled the outputs from the workshops to be tested and refined. The main graphical outputs, and the results have been published on the internet to encourage dissemination and comment.

A ninth workshop focused on crosscutting themes and synergies, drawing on the results from the eight sector workshops. This was enabled by the use of consistent structures and workshop methods across all eight sectors. As well as common technological issues, a large degree of commonality in industry drivers was observed across the eight sectors.

4 www.technology-roadmaps.co.uk

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