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# Technology roadmapping—A planning framework for evolution and revolution

Robert Phaal*, Clare J.P. Farrukh, David R. Probert

*Department of Engineering, University of Cambridge, Mill Lane, Cambridge, CB2 1RX, UK*

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**Abstract**

Technology roadmapping is a flexible technique that is widely used within industry to support strategic and long-range planning. The approach provides a structured (and often graphical) means for exploring and communicating the relationships between evolving and developing markets, products and technologies over time. It is proposed that the roadmapping technique can help companies survive in turbulent environments by providing a focus for scanning the environment and a means of tracking the performance of individual, including potentially disruptive, technologies. Technology roadmaps are deceptively simple in terms of format, but their development poses significant challenges. In particular the scope is generally broad, covering a number of complex conceptual and human interactions.

This paper provides an overview of the origins of technology roadmapping, by means of a brief review of the technology and knowledge management foundations of the technique in the context of the fields of technology strategy and technology transitions. The rapidly increasing literature on roadmapping itself is presented in terms of a taxonomy for classifying roadmaps, in terms of both organizational purpose and graphical format. This illustrates the flexibility of the approach but highlights a key gap—a robust process for technology roadmapping. A fast-start method for technology roadmapping developed by the authors is introduced and described. Developed in collaboration with industry, this method provides a means for improved understanding of the architecture of roadmaps and for rapidly initiating roadmapping in a variety of organizational contexts.

This paper considers the use of the roadmaps from two main perspectives. The first is a company perspective: roadmaps that allow technology developments to be integrated with business planning, and the impact of new technologies and market developments to be assessed. The second perspective is multiorganizational: roadmaps that seek to capture the environmental landscape, threats and opportunities for a particular group of stakeholders in a technology or application area. Two short

* Corresponding author.
*E-mail address:* rp108@eng.cam.ac.uk (R. Phaal).


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illustrative cases show the fast-start method in use in the context of disruptive technological trends from these two perspectives.


*Keywords:* Technology roadmapping; Evolution; Revolution

## 1. Introduction

Many managers are aware of the strategic importance of technology in delivering value and competitive advantage to their companies and the industrial networks in which they operate. These issues are becoming more critical as the cost, complexity and rate of technology change increases, and competition and sources of technology globalize. The management of technology for business benefit requires effective processes and systems to be put in place to ensure that existing and potential technological resources within the organization are aligned with its needs, now and in the future. In addition, the impact of changes in technology and markets need to be assessed, in terms of potential threats and opportunities, including disruptive technologies and markets [1]. Technology roadmaps have great potential for supporting the development and implementation of integrated strategic business, product and technology plans, providing companies have the information, process and tools to produce them. Roadmaps and the roadmapping process can provide a means for enhancing an organization's 'radar', in terms of extending planning horizons, together with identifying and assessing possible threats and opportunities in the business environment. For example, roadmaps can be used as a means for assessing the impact of potentially disruptive technologies and markets on business plans and systems.

Following on from a brief literature review of technology management, technology strategy and technology transitions, this paper focuses on technology roadmapping, an approach that is being increasingly applied within industry to support the development, communication and implementation of technology and business strategy. Roadmapping is a very flexible approach, and the various aims that it can support are reviewed, together with the different formats that roadmaps take. Also important is the process that is required to develop a good roadmap. The paper describes a method for rapid initiation of roadmapping in an organization, how it can be customised for multicompany use, together with some of the characteristics of good roadmaps and the systems needed for supporting their application. Two cases are presented showing the application of the roadmapping process in disruptive environments.

## 2. Literature review

### 2.1. Technology and the management of technology

There are many published definitions of technology [2–4]. Examination of these definitions highlights a number of factors that characterize technology, which can be considered as a specific type of knowledge (although this knowledge may be embodied within a physical artifact, such as a machine, component, system or product). The key characteristic of technology that distinguishes it from more general knowledge types is that it is *applied*, focusing on the know-how of the organization. While technology is usually associated with science and engineering ('hard' technology), the processes that enable its effective application are also important—for example, new product development and innovation processes, together with organizational structures and supporting knowledge networks ('soft' aspects of technology).

Treating technology as a type of knowledge is helpful, as knowledge management concepts can be useful for more effectively managing technology [5–7]. For instance, technological knowledge generally comprises both explicit and tacit knowledge. Explicit technological knowledge is that which has been articulated (for example in a report, procedure or user guide), together with the physical manifestations of technology (equipment). Tacit technological knowledge is that which cannot be easily articulated, and which relies on training and experience (such as welding or design skills).

Similarly, there are many definitions of technology management in the literature [8,9]. For the purposes of this paper the following definition is adopted, proposed by the European Institute of Technology and Innovation Management (EITIM):

> Technology management addresses the effective identification, selection, acquisition, development, exploitation and protection of technologies (product, process and infrastructural) needed to achieve, maintain [and grow] a market position and business performance in accordance with the company's objectives [10].

This definition highlights two important technology management themes:

1. Establishing and maintaining the linkages between technological resources and company objectives is of vital importance and represents a continuing challenge for many firms. This requires effective communication and knowledge management, supported by appropriate tools and processes. Of particular importance is the dialogue and understanding that needs to be established between the commercial and technological functions in the business.
2. Effective technology management requires a number of management processes and the EITIM definition includes the five processes proposed by Gregory [11]: identification, selection, acquisition, exploitation and protection of technology. These processes are not always very visible in firms, and are typically distributed within other business processes, such as strategy, innovation and operations.

Technology management addresses the processes needed to maintain a stream of products and services to the market. It deals with all aspects of integrating technological issues into business decision making, and is directly relevant to a number of business processes, including strategy development, innovation and new product development, and operations management. Healthy technology management requires establishing appropriate knowledge flows between commercial and technological perspectives in the firm, to achieve a balance between market 'pull' and technology 'push'. The nature of these knowledge flows depends on both the internal and external context, including factors such as business aims, market dynamics, organizational culture and technological context. These concepts are illustrated in Fig. 1 [12].

### 2.2. Technology strategy

The effective integration of technological considerations into business strategy is an important aspect of business planning. A key premise is that a technology strategy should not be developed independently from the business strategy, but rather that technological resources should be considered as an integral part of business planning [13,14]. Business strategy is concerned with aligning the activities of the firm in such a way as to generate a sustainable competitive position in the market place [15]. This requires a sound understanding of both the nature of the changing business environment in the medium to long term and the capabilities of the firm. Indeed, Prahalad and Hamel [16] suggest that it is only by 'envisioning markets that do not yet exist that management will fully realize the potential that core competencies create'.

Technological considerations include both external factors, such as the nature of technological change and competitor activity, and internal factors such as technological capabilities. Three key questions can be used to stimulate the development of a business strategy [17], each involving technological considerations:

- What basis?—The selection of a generic strategic approach (e.g., cost leadership, differentiation or focus)

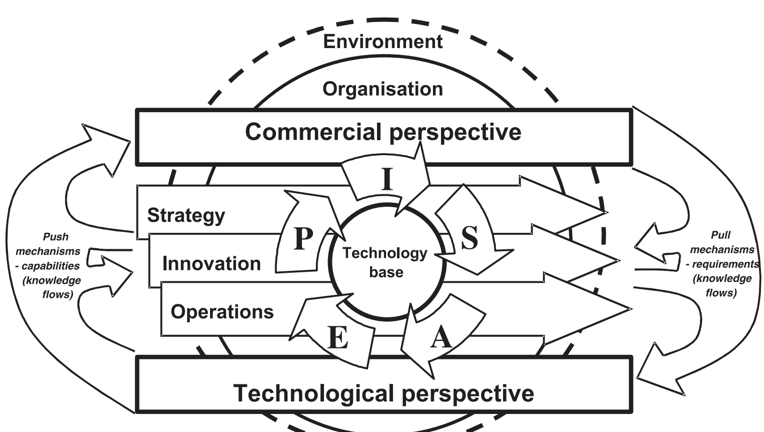


Fig. 1. Technology management framework [12], showing technology management processes (*i*dentification, *s*election, *a*cquisition, *e*xploitation and *p*rotection), business processes (strategy, innovation and operations), highlighting the dialogue that is needed between the commercial and technological functions in the business to support effective technology management.

- Which direction?—Identification and selection of alternative directions (e.g., do nothing, withdraw, consolidation, market penetration, product development, market development, integration, diversification)
- How?—The identification and selection of alternative methods (e.g., internal development, acquisition, joint development).

Many approaches to developing technology strategy have been published (e.g., [2,18–20]]), but there is an increasing industrial focus on tools and techniques that can support such approaches, such as strategic analysis tools [21,22] and methods for technology audit [14,23,24]. An important aspect of such tools is that they promote collective discussion and bridge the gap between market and technology opportunities and developments.

*2.3. Technology transitions*

Incremental and radical technological change can be understood in terms of technology S-curves. An S-curve represents technical performance as a function of time or research effort [25] and its shape is influenced by market demand, scientific knowledge and level of investment or innovation [26]. As a technology matures substantial improvements in performance become impossible, owing to economic or technical constraints. As the technology approaches the top of its S-curve potential technologies compete, resulting in a turbulent environment until a new dominant design emerges. This is a technological discontinuity [27] as 'almost by definition, the S-curves of different technologies are not linked. . . and to manage the transition is a difficult and delicate task' [25]. Focusing on the management of disruptive technology draws attention to the nature of innovation, including the need for innovation 'streams' rather than discrete innovations, and the necessary organizational tension between internal diversity and balance [28]. The impact of technological shifts on 'previous ways of organizing production, industry, culture and society' are also key [29]. Work on technology transitions as evolutionary reconfiguration processes [30–32] raises the level of analysis wider than a single company. This views the dynamics of sociotechnical change in three layers [31,32]:

- Macro: evolving sociotechnical landscapes
- Meso: a patchwork of regimes
- Micro: novel configurations.

Together, this tripart view of technology transitions, at company and societal levels, suggests a highly dynamic vision of the future, which is the backdrop to any technological and business planning situation.

*2.4. Technology roadmaps*

Technology roadmapping represents a powerful technique for supporting technology management and planning, especially for exploring and communicating the dynamic linkages between technological resources, organizational objectives and the changing environment.

Roadmapping has been widely adopted in industry [33–38]. Roadmaps can take various forms, ranging between the two extremes of technology push (divergent and looking for opportunities) and market pull (aiming for customer defined product). The most common approach is encapsulated in the generic form proposed by EIRMA [36], illustrated in Fig. 2. The generic roadmap is a time-based chart, comprising a number of layers that typically include both commercial and technological perspectives. The roadmap enables the evolution of markets, products and technologies to be explored, together with the linkages and discontinuities between the various perspectives. The roadmapping technique can be seen to draw together key themes from the technology strategy and transitions literature, by the use of its layered structure in conjunction with the dimension of time.

Probert and Radnor [41] identify the early roots of the approach in the U.S. automotive industry, with Motorola and Corning developing systematic approaches in the late 1970s and early 1980s. The Motorola approach has been more visible, leading to take up of the concept in the consumer electronics sector, most notably Philips [37], Lucent Technologies [42] and the SIA [39]. This exposure led to the much wider adoption of the approach by consortia and governments to support sector-level research collaboration (e.g., [40,55,66]), as can be readily demonstrated by an Internet search using the term 'technology roadmapping'. Many other approaches are closely related to technology roadmapping, such as forecasting, foresight, futures, Delphi, scenario planning, backcasting and other general approaches to technology strategy development [43–51].

The roadmapping approach has been adapted by organizations to support many different types of strategic aims, and term technology roadmapping can refer to many related techniques and approaches. The particular feature (and benefit) of the technology roadmapping concept is the use of a time-based structured (and often graphical) framework to develop, represent and communicate strategic plans, in terms of the coevolution and development of technology, products and markets. In this regard, technology roadmapping is also closely related to other graphical planning approaches such as PERT (program evaluation and review technique) and Gantt planning tools [52].

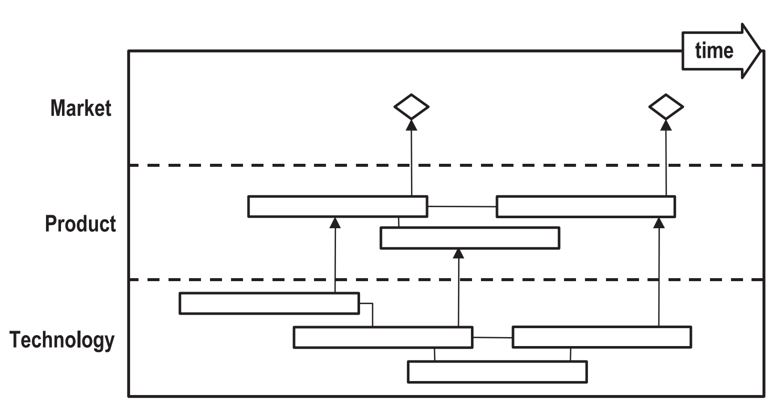


Fig. 2. Schematic technology roadmap, showing how technology can be aligned to product and service developments, business strategy, and market opportunities.

## 3. Types of technology roadmaps: purpose, format and use

The technology roadmapping approach is very flexible, in terms of the different organizational aims that it can address, and the range of graphical forms that roadmaps can take. Terms such as product, innovation, business or strategic roadmapping may be more appropriate for many of its potential uses. Examination of a set of approximately 40 roadmaps has revealed a range of different types, clustered into 16 broad areas (see Figs. 3–5), described in more detail in the following sections. These groups reflect both intended purpose and graphical format, based on observed structure and content [53].

### *3.1. Technology roadmaps: purpose*

The following eight types of roadmap have been identified, in terms of intended purpose:

(a) Product planning: This is by far the most common type of technology roadmap, relating to the insertion of technology into manufactured products, often including more than one generation of product. Fig. 4a shows a Philips roadmap, where the approach has been widely adopted [37]. The example shows how roadmaps are used to link planned technology and product developments.

(b) Service/capability planning: This type is more suited to service-based enterprises, focusing on how technology supports organizational capabilities. Fig. 4b shows a Royal Mail roadmap, based on an initial T-Plan application [54], used to investigate the impact of technology developments on the business. This roadmap focuses on organizational capabilities as the bridge between technology and the business, rather than products.

(c) Strategic planning: This type is suitable for general strategic appraisal, in terms of supporting the evaluation of different opportunities or threats, typically at the business

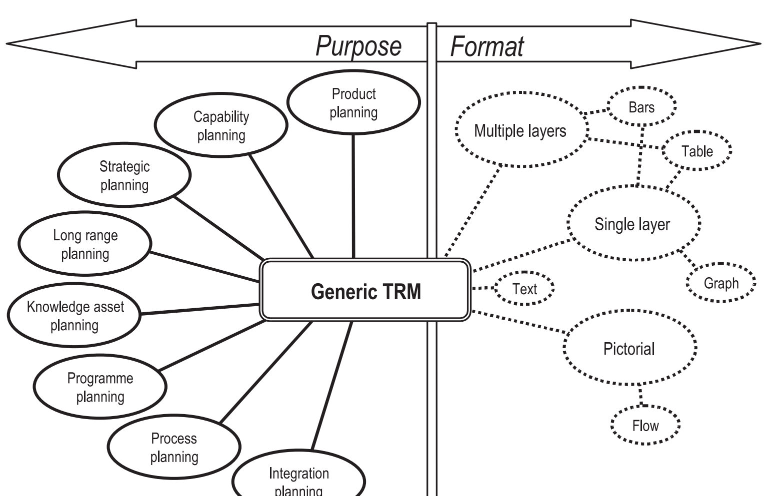


Fig. 3. Characterization of roadmaps: purpose and format [22].

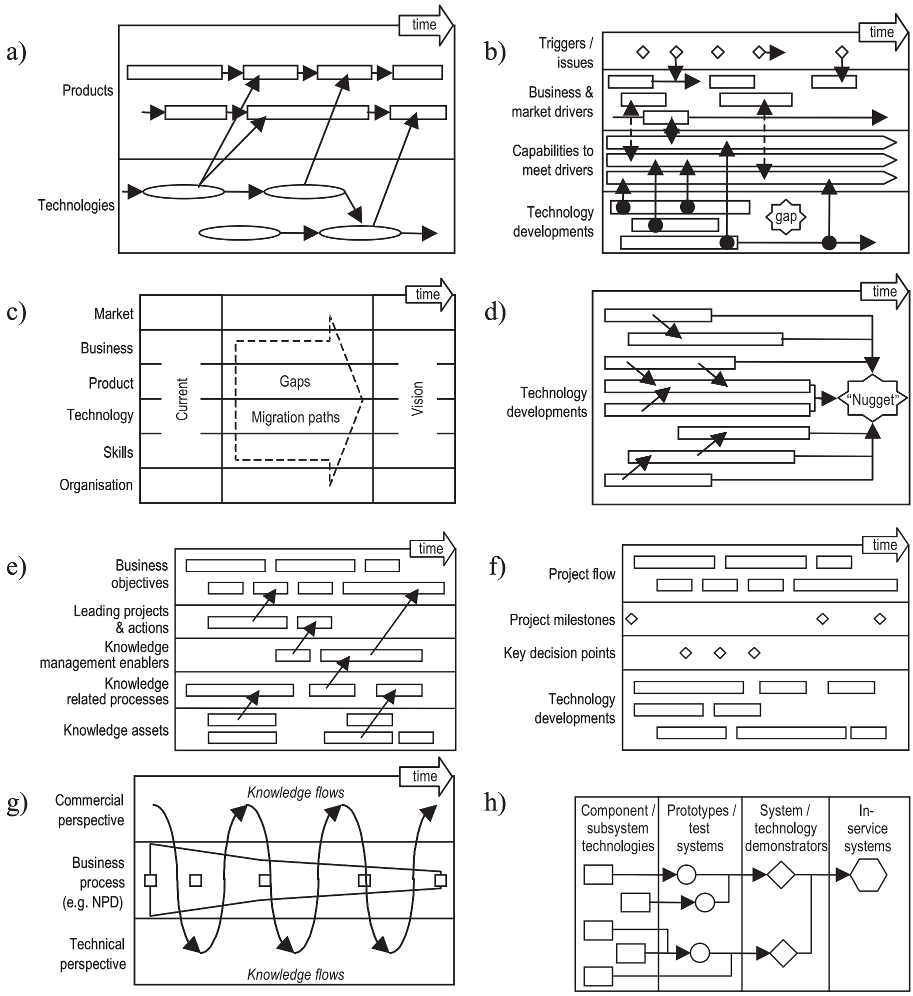


Fig. 4. Examples of technology roadmap types (purpose): (a) product planning [17]; (b) service/capability planning [23]; (c) strategic planning; (d) long-range planning [24]; (e) knowledge asset planning [25]; (f) program planning [26]; (g) process planning; (h) integration planning [26].

level. Fig. 4c shows a roadmap format developed using T-Plan to support strategic business planning. The roadmap focuses on the development of a vision of the future business, in terms of markets, business, products, technologies, skills, culture, etc. Gaps are identified, by comparing the future vision with the current position, and strategic options explored to bridge the gaps.

(d) Long-range planning: This type is used to support long-range planning, extending the planning horizon. Roadmaps of this type are often performed at the sector or national level (foresight), and can act as a radar for the organization to identify potentially disruptive technologies and markets. Fig. 4d shows one of a series of roadmaps developed within the U.S. Integrated Manufacturing Technology Roadmapping Initiative

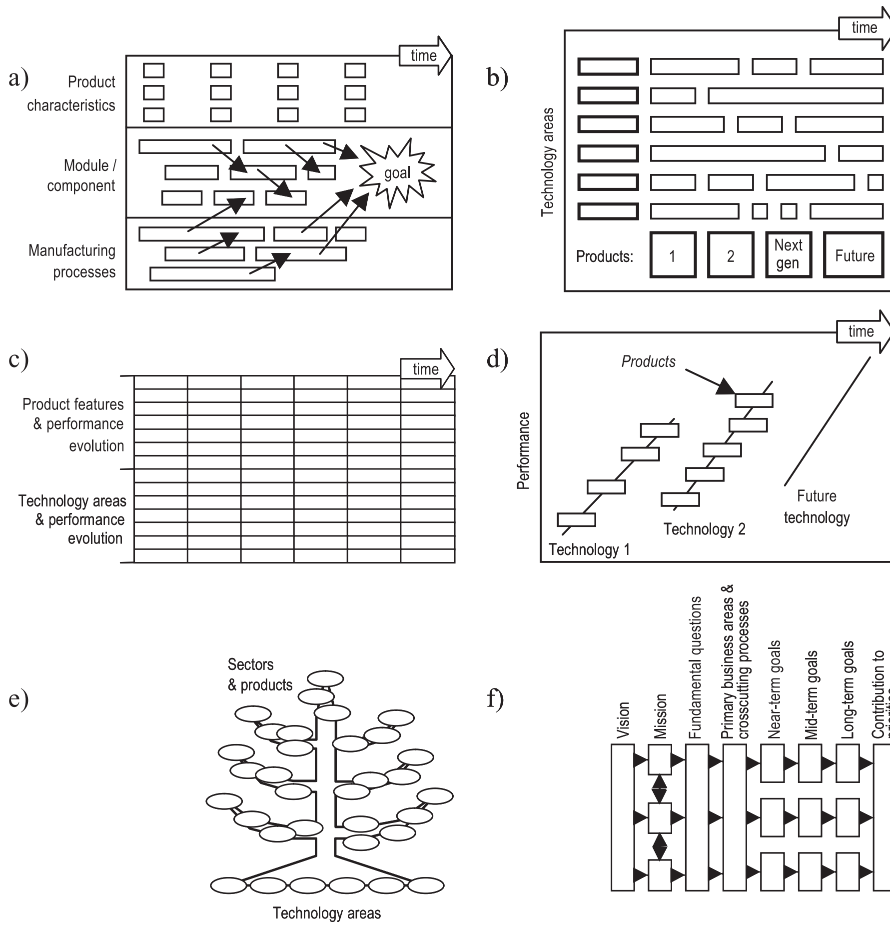


Fig. 5. Examples of technology roadmap types (format): (a) multiple layers [17]; (b) bars [13]; (c) tabular [16]; (d) graphical [16]; (e) pictorial [27]; (f) flow chart [28].

[55]. This example focuses on information systems, showing how technology developments are likely to converge towards the 'information-driven seamless enterprise'—a 'nugget'.

(e) Knowledge asset planning: This type aligns knowledge assets and knowledge management initiatives with business objectives. Fig. 4e shows an example developed by the Artificial Intelligence Applications Unit at the University of Edinburgh [56], enabling organizations to visualize their critical knowledge assets, and the linkages to the skills, technologies and competencies required to meet future market demands.

(f) Program planning: This type focuses on implementation of strategy, and more directly relates to project planning (for example, R&D programs). Fig. 4f shows a NASA roadmap (one of many) for the Origins program [57], used to explore how the universe and life within it has developed. This particular roadmap focuses on the management of the development program for the Next Generation Space Telescope (NGST), showing the relationships between technology development and program phases and milestones.

(g) Process planning: This type supports the management of knowledge, focusing on a particular process area (for example, new product development). Fig. 4g shows a roadmap developed using T-Plan to support product planning, focusing on the knowledge flows that are needed to facilitate effective new product development and introduction, incorporating both technical and commercial perspectives.

(h) Integration planning: This type focuses on integration and/or evolution of technology, in terms of how different technologies combine within products and systems, or to form new technologies (often without showing the time dimension explicitly). Fig. 4h shows a NASA roadmap [57], relating to the management of the development program for the NGST, focusing on technology flow, showing how technology feeds into test and demonstration systems, to support scientific missions.

### *3.2. Technology roadmaps: format*

The following eight types of roadmap have been identified, relating to graphical format:

(a) Multiple layers: This is the most common format of technology roadmap comprising a number of layers (and sublayers), such as technology, product and market. The roadmap allows the evolution within each layer to be explored, together with the interlayer dependencies, facilitating the integration of technology into products, services and business systems. Fig. 5a shows a Philips roadmap [37], used to support integration of product and process technologies to the development of functionality in future products.

(b) Bars: Many roadmaps are expressed in the form of a set of bars, for each layer or sublayer. This has the advantage of simplifying and unifying the required outputs, which facilitates communication, integration of roadmaps, and the development of software to support roadmapping. Fig. 5b shows a Motorola roadmap [33], relating to the evolution of car radio product features and technologies.

(c) Tables: In some cases, entire roadmaps, or layers within the roadmap, are expressed as tables (time vs. performance or requirements). This type of approach is particularly suited to situations where performance can be readily quantified, or if activities are clustered in specific time periods. Fig. 5c shows a tabular roadmap [36], including both product and technology performance dimensions.

(d) Graphs: Where product or technology performance can be quantified, a roadmap can be expressed as a simple graph or plot—typically one for each sublayer. This type of graph is sometimes called an experience curve, and is closely related to technology S-curves. Fig. 5d shows how products and technologies coevolve [36].

(e) Pictorial representations: Some roadmaps use more creative pictorial representations to communicate technology integration and plans. Sometimes metaphors are used to support the objective (e.g., a tree). Fig. 5e shows a Sharp roadmap [58], relating to the development of products and product families, based on a set of liquid crystal display technologies.

(f) Flow charts: A particular type of pictorial representation is the flow chart, which is typically used to relate objectives, actions and outcomes. Fig. 5f shows a NASA roadmap, illustrating how the organization's vision can be related to its mission, fundamental scientific questions, primary business areas, near-, mid- and long-term goals, and contribution to U.S. national priorities [59].
(g) Single layer: This form is a subset of Type A, focusing on a single layer of the multiple layer roadmap. While less complex, the disadvantage of this type is that the linkages between the layers are not generally shown. The Motorola roadmap [33] is an example of a single layer roadmap, focusing on the technological evolution associated with a product and its features (the graphical roadmap matrix is supported by additional documentation and software is used to link together roadmap layers).
(h) Text: Some roadmaps are entirely or mostly text based, describing the same issues that are included in more conventional graphical roadmaps (which often have text-based reports associated with them). The Agfa white papers support understanding of the technological and market trends that will influence the optics sector [60].

The range of roadmap types observed may be partially attributed to a lack of clear and accepted standards or protocols for their construction. However, it is considered that this also reflects the need to adapt the approach to suit the situation, in terms of business purpose, existing sources of information, available resources and desired use (the message being communicated). Roadmaps do not always fit neatly within the categories identified above and can contain elements of more than one type, in terms of both purpose and format, resulting in hybrid forms.

### *3.3. Technology roadmaps: use*

A recent survey of 2000 UK manufacturing firms [61] indicates that about 10% of companies (mostly large) have applied the technology roadmapping approach, with approximately 80% of those companies either using the technique more than once, or on an ongoing basis. However, application of the TRM approach presents considerable challenges to firms, as the roadmap itself, while fairly simple in structure and concept, represents the final distilled outputs from a strategy and planning process. Key challenges reported by survey respondents included keeping the roadmapping process 'alive' on an ongoing basis (50% of responding companies), starting up the TRM process (30%), and developing a robust TRM process (20%).

One of the reasons why companies struggle with the application of roadmapping is that there are many specific forms of roadmaps, which often have to be tailored to the specific needs of the firm and its business context. In addition, there is little practical support available and companies typically reinvent the process, although there have been some efforts to share experiences. For example Bray and Garcia [35], EIRMA [36], Groenveld [37] and Strauss et al. [38] summarize key technology roadmapping process steps. These authors indicate that the development of an effective roadmapping process within a business is reliant on significant vision and commitment for what is an iterative, and initially exploratory, process. However, these sources do not include detailed guidance on how to apply the approach. An attempt to fill this gap has been made by the development of the T-Plan fast-start approach.

## 4. Fast-start technology roadmapping

The T-Plan fast-start approach has been developed as part of a three-year applied research program, where more than 20 roadmaps were developed in collaboration with a variety of company types in several industry sectors (see Table 1). A case-based action research methodology was adopted for developing the roadmapping process [62], with several roadmapping applications undertaken for each of three phases (exploratory, development and test cases). More recently the general principles of the approach have been used to develop multiorganization (or collaborative) roadmaps, and to date the T-Plan approach has been applied more than 40 times.

The experience and learning resulting from the T-Plan applications were captured in a management guide [63], which aims to:

- Support the start-up of company-specific TRM processes.
- Establish key linkages between technology resources and business drivers.
- Identify important gaps in market, product and technology intelligence.
- Develop a first-cut technology roadmap.

Table 1
Applications leading to publication of T-Plan fast-start TRM process

| # | Case type | Product/sector | Business aims |
|---|---|---|---|
| 1 | Exploratory and development (two applications) | Industrial coding systems | Product planning for inkjet and laser printing |
| 2 | Exploratory, development and test (10 applications) | Postal and information services | Integration of technology and research into business; business planning; capability/service planning; definition of consortia research agenda |
| 3 | Development | Security/access systems | Product family planning |
| 4 | Test | Software (labeling) | Exploration of product opportunity |
| 5 | Development | Surface coatings | New product development planning |
| 6 | Development | Power transmission and distribution | Exploration of business opportunity for new technology |
| 7 | Development and test (two applications) | Railway infrastructure | Capital investment and technology insertion planning |
| 8 | Test | Automotive subsystems | Reliability service planning |
| 9 | Development and test (two applications) | Medical packaging | Exploration of new business model |
| 10 | Test | Building controls | Exploration of new business model |
| 11 | Development | Automotive sector | Definition of research agenda |

- Support technology strategy and planning initiatives in the firm.
- Support communication between technical and commercial functions.

The T-Plan process comprises two main parts:

1. Standard approach, for supporting product planning [64].
2. Customized approach, which includes guidance on the broader application of the method.

### 4.1. Standard process (product planning)

The standard T-Plan process comprises four facilitated workshops. The first three focus on the three main layers of the roadmap (market/business, product/service and technology), with the final workshop bringing the themes together on a time-basis to construct the chart (see Fig. 6). The approach is driven by market and business requirements, which are used to identify and prioritize product and technology options (as shown in Fig. 1). Thus, the process is driven predominantly by market pull, although one of the aims is to generate novel technology solutions that may give rise to new product and market opportunities. Also important are the parallel management activities, including planning and facilitation of workshops, process coordination and follow-up actions. Simple linked analysis grids are used to identify and assess the relationships between the various layers and sublayers in the roadmap, similar to in nature to the widely used QFD (quality function deployment) approach used in product and engineering design [52].

### 4.2. Customizing the process

As noted above, roadmapping can support a range of different business aims, including product planning, exploration of new opportunities, resource allocation and management, and improved business strategy and planning. In addition, each organization is different in terms

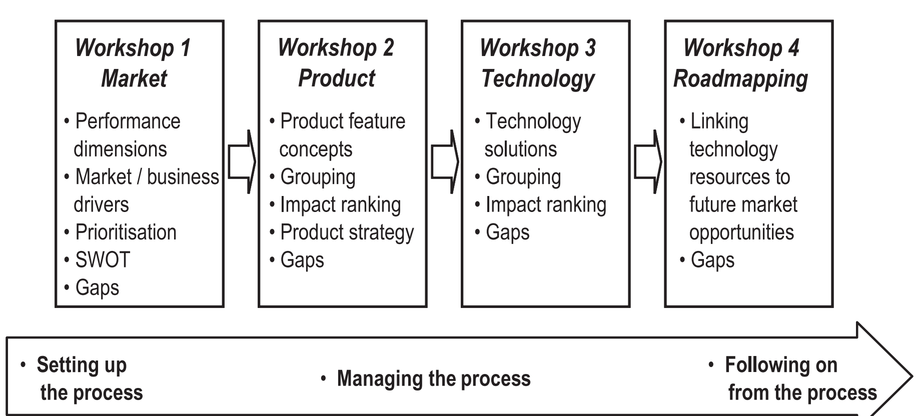


Fig. 6. T-Plan: standard process steps [31].

of its particular business context, organizational culture, business processes, available resources, technology types, etc. For these reasons, if the full benefits of roadmapping are to be gained, then it should be expected that the approach will need to be customized to suit the particular application. The multilayer roadmap is the most common form, and the most flexible in application, including the following dimensions:

(a) Time: This dimension can be adapted to suit the particular situation, in terms of time horizon (typically short in sectors such as e-commerce and software, and much longer for aerospace and infrastructure); scale (a logarithmic scale is typically used, with more space allocated to the short vs. long term); intervals (a continuous time scale can be used, or intervals such as six month, annual, or short, medium and long term). Space on the roadmap can also be allocated for vision and very long-range considerations, together with the current situation (and history), with respect to competition or to define the gap between the current position and the vision.
(b) Layers: The vertical axis of the roadmap is critical, as this needs to be designed to fit the particular organization and problem being addressed. Often a considerable part of the initial roadmapping effort will be directed at defining the layers and sublayers that will form the roadmap. Fig. 7 shows a generalized roadmap architecture, based on many roadmaps that have been developed and observed. The different types of layers on roadmaps are listed, highlighting the flexibility of the approach in terms of providing a framework for supporting strategic planning. The top layers relate to the organizational purpose that is driving the roadmap (know-why). The bottom layers relate to the resources (particularly technological knowledge) that will be deployed to

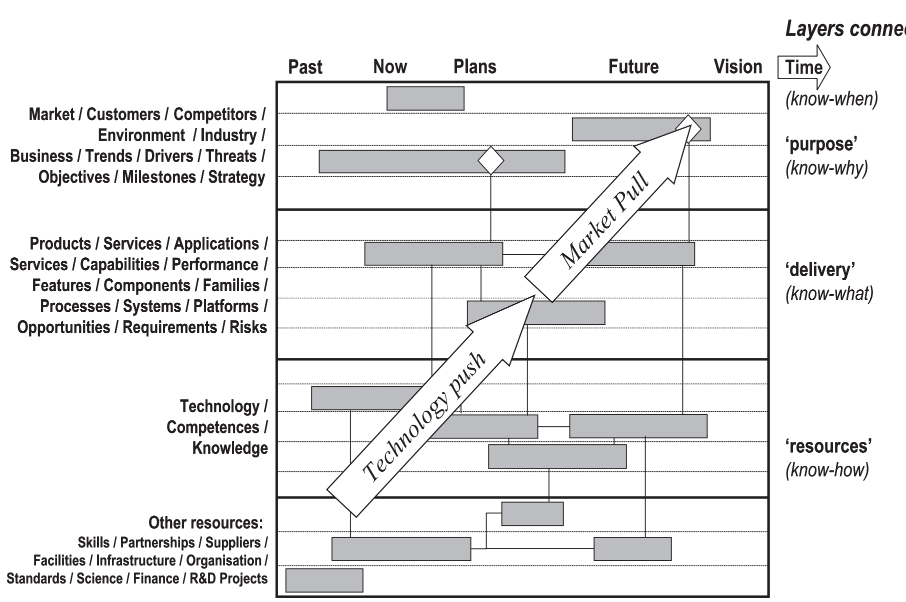


Fig. 7. Generalized technology roadmap architecture.

address the demand from the top layers of the roadmap (know-how). The middle layers of the roadmap are crucial, providing a bridging or delivery mechanism between the purpose and resources (know-what). Frequently the middle layer focuses on product development, as this is the route through which technology is often deployed to meet market and customer needs. However, for other situations services, capabilities, systems, risks or opportunities may be more appropriate for the middle layer, to understand how technology can be delivered to provide benefits to the organization and its stakeholders.

(c) Annotation: In addition to the information contained within the layers, on a time-basis, other information can be stored on the roadmap, including:
- Linkages between objects in layers and sublayers (of various possible kinds)
- Supplementary information, such as a key, statement of business strategy or market drivers, people involved in developing the roadmap and assumptions
- Other graphic devices, including objects, notes and color coding, to indicate key decision points, gaps, critical paths, opportunities and threats (including disruptive technologies and markets).

(d) Process: The steps that will be required to complete the first roadmap, and take the process forward thereafter, will typically be different for each organization (and often within the organization, too). The process that is most suitable depends on many factors, including the level of available resources (people, time, budget), nature of the issue being addressed (purpose and scope), available information (market and technology), other processes and management methods that are relevant (strategy, budgeting, new product development, project management and market research). Strategic planning usually involves balancing an external view of the firm (market and business environment) with an internal view (tangible and intangible assets). As shown in Fig. 8, combining these external and internal perspectives (opportunities, threats, strengths and weaknesses)

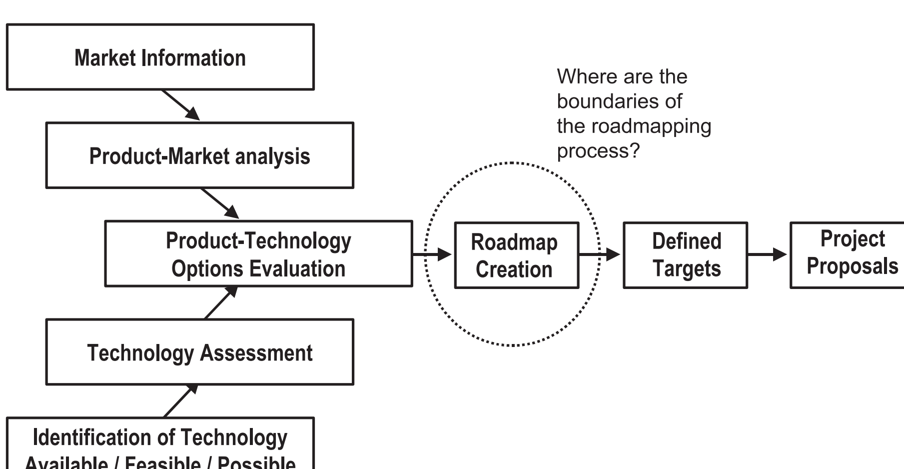


Fig. 8. Roadmaps integrate commercial and technological knowledge [16].

enables a set of product-technology options to be identified and evaluated. For this reason most roadmaps include aspects of both market pull and technology push (Fig. 7), where the direction and rate of technology, product and market development reflect a balance between these drivers. However, it should be recognized that a technology push approach is generally more divergent and complex compared to market pull, as a particular technology may have many applications in domains where the firm has limited experience. Most customized T-Plan applications have included a combination of market pull and technology push considerations, although generally firms have wished to express the strategic plan in a market-oriented fashion.

The planning phase is the most important consideration for customizing the roadmap and roadmapping process, to clearly articulate the business and process objectives and to think through how the generic process of roadmapping might help to achieve the objectives, given the particular situation and context. Ownership of the roadmap is critical, firstly by a single designated person or group of people (committee or steering group), then by those that will participate in its creation, and ultimately on a wider basis within the organization as a communication tool. If possible it is helpful to designate a person to manage the process and facilitate the workshops, ideally proficient in roadmapping. It may be necessary to bring in expertise from outside the organization from related technology fields, markets or industries to gain a wider view of potential opportunities and threats. Aligning the capabilities of the roadmapping method with business goals and context at the planning stage is important if a good roadmap structure and process are to be developed.

Although developed primarily for use from a company perspective the T-Plan method can also be customized for multiorganizational use, to capture the environmental landscape, threats and opportunities for a particular group of stakeholders in a technology or application area. Two short illustrative cases (Section 5) show the fast-start method in use in the context of disruptive technological trends. The first is for an individual company and the second for a group of organizations.

### *4.3. Taking the technology roadmapping process further*

The development of an initial roadmap is the first, but very important, step on the way towards implementing roadmapping in a more complete and beneficial way, if that is deemed appropriate. The key benefit of the fast-start T-Plan approach, apart from the direct business benefits that arise from its application, is that the value of the method can be assessed quickly and economically. The learning that is gained by this initial application provides confidence about how to best take the process forward within the organization.

While some companies choose to use this method for particular situations on a one-off basis, others have taken roadmapping forward to form a significant part of their strategy and planning processes. Roadmapping can become the focal, integrating device for carrying the business strategy and planning process forward, bringing together market/commercial and technological knowledge from inside and outside the organization (Fig. 8). Key issues include deciding where the boundaries of the roadmapping process should lie, to what extent the method should be adopted, and how to integrate it with other systems and processes. These issues apply equally to multiorganizational roadmapping.

There are two key challenges to overcome if roadmapping is to be adopted widely within a company:

(i) *Keeping the roadmap alive*: the full value of roadmapping can be gained only if the information that it contains is current and kept up-to-date as events unfold. In practice, this means updating the roadmap on a periodic basis, at least once a year, or perhaps linked to budget or strategy cycles. The initial first-cut roadmap produced by the T-Plan process must be captured, stored, communicated, researched and updated, which requires careful consideration of the process and systems needed to facilitate this.

(ii) *Roll-out*: once the first roadmap is developed, it may be desirable to facilitate the adoption of the method in other parts of the organization. Essentially there are two approaches to rolling-out the method:

- *Top-down*, where the requirement for roadmaps is prescribed by senior management—the particular format may or may not be specified.
- *Bottom-up ('organic')*, where the benefits of using the method are communicated and support provided for application where a potential fit with a business issue/problem is identified.

In either case senior management support is important, in terms of enthusiasm for use of the approach, but also in terms of ensuring that resources are made available (budget, time and facilitation), workshops scheduled and barriers removed.

A further issue to consider if the roadmapping method is to be used on an ongoing and more widespread basis is that of software for supporting the development, storage, dissemination and upkeep of roadmaps. Simple word processing, spreadsheet and graphics packages are suitable for the initial development of a roadmap, but more sophisticated software would be beneficial if the process is to be taken forward, and commercial dedicated software systems are starting to appear.

## 5. Case studies

These two short cases illustrate how roadmapping can be a useful tool in an environment of disruptive change.

### *5.1. Illustrative case 1—single organization perspective*

Domino Printing Sciences started to roadmap using the Standard T-Plan process in 1998 when it decided that it needed stronger technical input for a new strategic planning process. The UK-based company was aware that its existing ink jet printing technology was reaching maturity and had recently purchased new technological capability in laser printing by acquiring a U.S. firm. Both the established and new business units have carried out useful

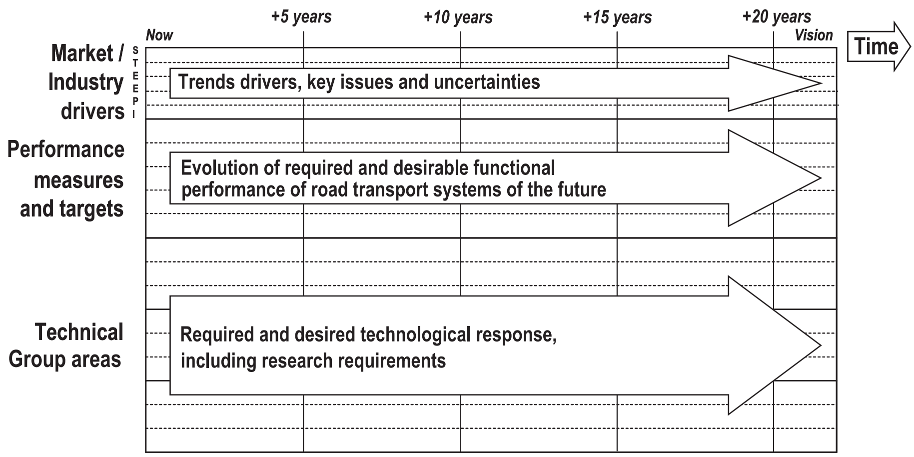


Fig. 9. Foresight Vehicle technology roadmap: architecture.

roadmapping applications [65]. One established business unit realised that it did not have a sufficiently good understanding of the market, so it commissioned and took part in a six months market assessment before returning to its roadmapping process. The new business unit found that roadmapping showed that an enabling technology could be marketed separately as a product and that, contrary to previous belief, it did not need to go outside the company for a particular technical capability. During a recent acquisition of a German laser company, the roadmapping method was used to plan the integration of product and technology platforms.

### 5.2. Illustrative case 2—multiorganization perspective

The UK Foresight Vehicle roadmapping initiative [66] has used a customized version of the T-Plan process to chart the future for road vehicles from a multistakeholder perspective (Fig. 9). The initiative involved 10 workshops over 10 months, with 130 people participating from over 60 organisations. One of the technology elements of the roadmap shows how the fuel cell is expected to develop and challenge the internal combustion engine [54 p18], highlighting how transitional phases involving hybrid vehicles may bridge the gap while the technology and necessary infrastructure develop. The overall roadmap provides a common framework and resource for the sector to collectively address the challenges facing the road transport system.

## 6. Summary and conclusions

Identifying disruptive technologies and surviving in disruptive markets is not easy but roadmaps can help. Tushman et al. [28] state that products should be seen as being ‘made up of a set of subsystems, each of which has its own innovation stream’ and that there is a need for 'articulating a clear, common, shared vision' in a company simultaneously carrying out incremental and radical innovation. It is suggested that in both areas technology roadmapping provides a significant step forward. The following general characteristics of technology roadmaps have been identified:

- The generic roadmapping approach has great potential for supporting business strategy and planning beyond its product and technology planning origins. However, it should be recognized that it is not a 'black box' methodology, that each application is a learning experience, and that a flexible approach is required, adapted to the particular circumstances being considered.
- Many of the benefits of roadmapping are derived from the roadmapping process, rather than the roadmap itself. The process brings together people from different parts of the business, providing an opportunity for sharing information and perspectives and providing a vehicle for holistic consideration of problems, opportunities and new ideas. The main benefit of the first roadmap that is developed is likely to be the communication that is associated with the process, and a common framework for thinking about strategic planning in the business. Several iterations may be required before the full benefits of the approach are achieved, with the integrated roadmap having the potential to drive the strategic planning process.
- The graphical form of the roadmap is a powerful communication mechanism, however, it can present information in a highly synthesized and condensed form. Hence, the roadmap should be supported by appropriate documentation.
- Roadmaps are multilayered, reflecting the integration of technology, product and commercial perspectives in the firm, including internal and external sources and supporting communication across functional boundaries in the organization. The structure that is adopted for defining the layers and sub-layers of the roadmap is important, and reflects fundamental aspects of the business and issues being considered. Typically these layers relate to key knowledge-based dimensions in the business, such as know-why, know-what, know-how, know-when, know-who, and know-where.
- Roadmaps explicitly show the time dimension, which is important both for ensuring that technological, product, service, business and market developments are synchronized effectively and for reflecting the dynamic, changing natures of technological and business environments. Roadmaps provide a means of charting a migration path between the current state of the business (for each layer), and the long-term vision, together with the linkages between the layers, in a form that is flexible enough to be updated over time.
- Software has an important role to play in supporting the application of roadmapping in the enterprise. However, software alone cannot deliver good roadmaps, and needs to be integrated with the human aspects of roadmapping. A key benefit of roadmapping is the sharing of knowledge and the development of a common vision of where the company is going, and this only comes about by sharing knowledge and making connections.
- Sectoral or multiorganization roadmapping promotes knowledge sharing and facilitates the development of a collective vision that can lead to action and collaboration.

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**Robert Phaal** is a Senior Research Associate within the Engineering Department at the University of Cambridge and a member of the Centre for Technology Management. Research interests include technology strategy and planning, management processes and decision support. Robert has a mechanical engineering background, a PhD in computational mechanics, with industrial experience in technical research, consulting and software development.

**Clare Farrukh** is a Senior Research Associate within the Engineering Department at the University of Cambridge and a member of the Centre for Technology Management. Research interests include technology strategy and planning, and management processes. Clare has a background in chemical engineering, with industrial experience in process plant and composites manufacturing.

**David Probert** is Head of the Centre for Technology Management and a Senior Lecturer at the University of Cambridge. David has a mechanical and manufacturing engineering background, with an industrial career with Marks and Spencer and Philips for 18 years before returning to Cambridge in 1991. His experience covers a wide range of industrial engineering and management disciplines in the UK and overseas.