Abstract

The technology roadmapping method is used widely in industry to support technology strategy and planning. The approach was originally developed by Motorola more than 25 years ago, to support integrated product-technology planning. Since then the technique has been adapted and applied in a wide variety of industrial contexts, at the company and sector levels (for example, the International Semiconductor and UK Foresight Vehicle technology roadmaps). Technology roadmaps can take many forms, but generally comprise multi-layered time-based charts that enable technology developments to be aligned with market trends and drivers.

This chapter provides an overview to the technology roadmapping approach, starting with an introduction to the topic of technology management. Roadmapping is a very flexible approach, and the various aims that it can support are reviewed, together with the different formats that roadmaps take and the principles for customising the method. Also important is the process that is required to develop a good roadmap, and the chapter describes a method for rapid initiation of roadmapping in the business strategy, together with some of the characteristics of good roadmaps and the systems needed for supporting their application. Case examples are included to illustrate how the approach can be applied at the sector level, based on collaborative workshops.

Introduction

Technology-driven innovation is of increasing importance to industry and nations, as a means of achieving the economic, social and environmental goals that lie at the heart of sustainable development. The effective management of technology is becoming more challenging as the cost, complexity and pace of technology change increase, in a globally competitive market. The management of technology for business and national benefit requires effective processes and systems to be put in place to ensure that investment in R&D, facilities and skills is aligned with market and industry needs, now and in the future.

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This paper provides an overview to the technology roadmapping approach, starting with an introduction to the topic of technology management. Roadmapping is a very flexible approach, and the various aims that it can support are reviewed, together with the different formats that roadmaps take and the principles for customising the method. Also important is the process that is required to develop a good roadmap, and the paper describes a method for rapid initiation of roadmapping in organisations, together with some of the characteristics of good roadmaps and the systems needed for supporting their application. A case example is included to illustrate how the approach can be applied at the sector level, based on a series of collaborative workshops.

Much of this paper focuses on the management of technology from the perspective of the manager at the firm level, where many of the techniques have evolved, but it should be recognised that the principles and approaches discussed can also be applied at the sector or national level.

**Technology and the management of technology**

There are many published definitions of ‘technology’ (for example, Floyd 1997, Whipp 1991, Steele 1989). Examination of these definitions highlights a number of factors that characterise technology, which can be considered as a specific type of knowledge (although this knowledge may be embodied within a physical artefact, 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 organisation. While technology is usually associated with science and engineering (‘hard’ technology), the processes which enable its effective application are also important - for example new product development and innovation processes, together with organisational 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 (for example, Stata, 1989, Nonaka, 1991, Leonard-Barton, 1995). 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 to ‘technology’, there are many definitions of ‘technology management’ in the literature (for example, Roussel et al., 1991, Gaynor, 1996). For the purposes of this paper the following definition is adopted, proposed by the European Institute of Technology Management (EITM):²

²Technology management addresses the effective identification, selection, acquisition, development, exploitation and protection of technologies (product, process and

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² EITM is a collaboration between a number of European universities: see http://www-mmd.eng.cam.ac.uk/ctm/eitm/index.html
infrastructural) needed to maintain [and grow] a market position and business performance in accordance with the company's objectives.

This definition highlights two important technology management themes:

- 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.

- Effective technology management requires a number of management processes and the EITM definition includes the five processes proposed by Gregory (1995): 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, organisational culture, etc. These concepts are illustrated in Fig. 1.

**Figure 1:**

Fig. 1 - Technology management framework (Probert et al., 2000), showing technology management processes (Identification, Selection, Acquisition, Exploitation and Protection), 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
Technology roadmaps

Technology roadmapping represents a powerful technique for supporting technology management and planning in the firm. Roadmapping has been widely adopted in industry (Willyard and McClees, 1987, Barker and Smith, 1995, Bray and Garcia, 1997, EIRMA, 1997, Groenveld, 1997, Strauss et al., 1998, Albright and Kappel, 2003, McMillan, 2003). More recently roadmaps have been used to support national and sector ‘foresight’ initiatives; for example, the Semiconductor Industry Association (SIA)\(^2\) (Kostoff and Schaller, 2001), Aluminum Industry\(^3\), UK Foresight Vehicle\(^4\) (Phaal, 2002) technology roadmaps. An Internet search using the term ‘technology roadmap’ will produce thousands of links, mostly relating to sector level initiatives, many of which are available to download (although there is considerable activity at the company level, this is seldom published for reasons of confidentiality).

Roadmaps can take various forms, but the most common approach is encapsulated in the generic form proposed by EIRMA (1997) - see 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 between the various perspectives.

Figure 2:

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

A survey of 2,000 UK manufacturing firms (Phaal et al., 2000) 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

\(^2\) http://public.itrs.net/files/1999_SIA_Roadmap/Home.htm
\(^3\) http://www.oit.doe.gov/aluminum/
\(^4\) http://www.foresightvehicle.org.uk/
'alive' on an ongoing basis (50%), starting up the TRM process (30%), and developing a robust TRM process (20%) - see Fig. 3.

**Figure 3:**

![Graph showing technology roadmapping challenges](image)

Fig. 3 - Key technology roadmapping challenges

One of the reasons why organisations struggle with the application of roadmapping is that there are many specific forms of roadmap, 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 re-invent the process, although there have been some efforts to share experience. For instance EIRMA (1997), Bray & Garcia (1997), Groenveld (1997), Strauss et al., (1998) and DoE (2000) summarise key technology roadmapping process steps. These authors indicate that the development of an effective roadmapping process within an organisation is reliant on significant vision and commitment for what is an iterative, and initially exploratory, process. More recently, a number of guidance notes have been published that relate to the application of the technology roadmapping approach at the sector level, in Australia\(^5\) and Canada\(^6\). These documents provide useful guidance on the principles and practice of technology roadmapping, and are a useful input to the design of a roadmapping process or activity. Many of the sector-level technology roadmaps that have been published on the Internet also provide useful guidance and examples. However, examination of these documents also reveals the variety of approaches that can be taken, which can be attributed to the flexibility of the roadmapping concept. In general it is necessary to customise the roadmapping approach to suit the particular circumstances for which it is intended, as discussed later in this paper.

Other factors that contribute to (and hinder) successful technology roadmapping are shown in Fig. 4, based on results from the survey described above. Factors that are particularly important for successful roadmapping (greater than 50% response) include a clearly articulated business need, the desire to develop effective business processes, having the right people involved and commitment from senior management. Factors that particularly hinder successful roadmapping include initiative overload, distraction from short-term tasks and required data, information and knowledge not being available.


This paper presents an overview of the technology roadmapping technique, including the range of aims that the approach can support, and the various formats that roadmaps take. A process for the rapid initiation of roadmapping in the firm is presented (T-Plan), together with the general requirements for supporting the process in the firm.

**Technology roadmapping approaches**

**Technology roadmapping approaches - purpose**

The technology roadmapping approach is very flexible, and the terms ‘product’ or ‘business’ 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 aims, clustered into the following eight broad areas, based on observed structure and content (Phaal et al., 2001a); see Fig. 5:

1. **Product planning**

   Description: 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. Example: A Philips roadmap, where the approach has been widely adopted (Groenveld, 1997). The example shows how roadmaps are used to link planned technology and product developments.
Technology Roadmapping

2. Service/capability planning
Description: Similar to Type 1 (product planning), but more suited to service-based enterprises, focusing on how technology supports organisational capabilities.
Example: A Post Office roadmap/T-Plan\(^7\) application (Brown, 2001), used to investigate the impact of technology developments on the business. This roadmap focuses on organisational capabilities as the bridge between technology and the business, rather than products.

3. Strategic planning
Description: Includes a strategic dimension, in terms of supporting the evaluation of different opportunities or threats, typically at the business level.
Example: 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.

4. Long-range planning
Description: Extends the planning time horizon, and is often performed at the sector or national level (‘foresight’).
Example: A roadmap developed within the US Integrated Manufacturing Technology Roadmapping (IMTR) Initiative\(^8\) (one of a series). This example focuses on information systems, showing how technology developments are likely to converge towards the ‘information driven seamless enterprise’ (a ‘nugget’).

5. Knowledge asset planning
Description: Aligning knowledge assets and knowledge management initiatives with business objectives.
Example: This form of roadmap has been developed by the Artificial Intelligence Applications Unit at the University of Edinburgh (Macintosh et al., 1998), enabling organisations to visualise their critical knowledge assets, and the linkages to the skills, technologies and competences required to meet future market demands.

\(^7\) Several of the example roadmaps have been developed during applications of the T-Plan ‘fast-start’ roadmapping process
\(^8\) IMTR (1999), Integrated manufacturing technology roadmapping (IMTR) project - information systems for the manufacturing enterprise, http://imti21.org/
6. Programme planning
Description: Implementation of strategy, and more directly relates to project planning (for example, R&D programmes).
Example: A NASA roadmap (one of many) for the Origins programme\(^9\), used to explore how the universe and life within it has developed. This particular roadmap focuses on the management of the development programme for the Next Generation Space Telescope (NGST), showing the relationships between technology development and programme phases and milestones.

7. Process planning
Description: Supports the management of knowledge, focusing on a particular process area (for example, new product development).
Example: A type of technology 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.

8. Integration planning
Description: 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).
Example: A NASA roadmap\(^7\) (Origins programme - see #6), relating to the management of the development programme for the NGST, focusing on 'technology flow', showing how technology feeds into test and demonstration systems, to support scientific missions.

Technology roadmapping approaches - format

Another factor that contributes to the variety of roadmaps that have been observed is the graphic format that has been selected for communicating the roadmap, with the following eight graphic types identified, based on observed structure (Phaal et al., 2001a):

a. Multiple layers
Description: The most common format of technology roadmap comprises a number of layers, such as technology, product and market. The roadmap allows the evolution within each layer to be explored, together with the inter-layer dependencies, facilitating the integration of technology into products, services and business systems.
Example: A Philips roadmap (Groenveld, 1997), showing how product and process technologies integrate to support the development of functionality in future products.

b. Bars
Description: Many roadmaps are expressed in the form of a set of ‘bars’, for each layer or sub-layer. 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. Example: The ‘classic’ Motorola roadmap (Willyard and McClees, 1987), showing the evolution of car radio product features and technologies. Motorola has subsequently developed roadmapping to new levels, with roadmaps now forming part of corporate knowledge and business management systems, supported by software and integrated decision support systems (Bergelt, 2000).

c. Tables
Description: In some cases, entire roadmaps, or layers within the roadmap, are expressed as tables (i.e. time vs. performance). This type of approach is particularly suited to situations where performance can be readily quantified, or if activities are clustered in specific time periods. Example: A tabulated roadmap (EIRMA, 1997), including both product and technology performance dimensions.

d. Graphs
Description: Where product or technology performance can be quantified, a roadmap can be expressed as a simple graph or plot - typically one for each sub-layer. This type of graph is sometimes called an ‘experience curve’, and is closely related to technology ‘S-curves’. Example: A roadmap showing how a set products and technologies co-evolve (EIRMA, 1997).

e. Pictorial representations
Description: 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’). Example: A Sharp roadmap\(^{10}\), relating to the development of products and product families, based on a set of liquid crystal display technologies.

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f. Flow charts
Description: A particular type of pictorial representation is the flow chart, which is typically used to relate objectives, actions and outcomes.
Example: A NASA roadmap\textsuperscript{11}, showing how the organisation’s vision can be related to its mission, fundamental scientific questions, primary business areas, near-, mid- and long-term goals, and contribution to US national priorities.

g. Single layer
Description: 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.
Example: The Motorola roadmap (Willyard and McClees, 1987), type ‘b’ above, is an example of a single layer roadmap, focusing on the technological evolution associated with a product and it’s features.

h. Text
Description: 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).
Example: The Agfa ‘white papers’ support understanding of the technological and market trends that will influence the sector\textsuperscript{12}.

**Figure 5:**

![Figure 5 - Characterisation of roadmaps: purpose and format](image-url)


\textsuperscript{12} Agfa white papers (1999), http://www.agfa1to1.com/whitepapers.html
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.

Technology roadmapping - process

The T-Plan ‘fast-start’ approach has been developed as part of a three-year applied research programme, where more than 35 roadmaps were developed in collaboration with a variety of company types in several industry sectors (see Table 1). A management guide has been written to support the application of the T-Plan approach (Phaal et al., 2001b), which aims to:

1. Support the start-up of company-specific TRM processes.
2. Establish key linkages between technology resources and business drivers.
3. Identify important gaps in market, product and technology intelligence.
4. Develop a ‘first-cut’ technology roadmap.
5. Support technology strategy and planning initiatives in the firm.
6. Support communication between technical and commercial functions.

The T-Plan process that has been developed to support the rapid initiation of roadmapping in the business comprises two main parts:

a. Standard approach, for supporting product planning (Phaal et al., 2000).
b. Customised approach, which includes guidance on the broader application of the method, incorporating many of the techniques included in the standard approach.

<table>
<thead>
<tr>
<th>Sector / product</th>
<th>Focus / aims</th>
</tr>
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<tbody>
<tr>
<td>Industrial coding (3 apps)</td>
<td>Product planning</td>
</tr>
<tr>
<td>Postal services (10 apps)</td>
<td>Integration of R&amp;D into business; business planning</td>
</tr>
<tr>
<td>Security / access systems</td>
<td>Product planning</td>
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<tr>
<td>Software</td>
<td>Product planning</td>
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<tr>
<td>Surface coatings</td>
<td>New product development process</td>
</tr>
<tr>
<td>Medical packaging (2 apps)</td>
<td>Business reconfiguration</td>
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<tr>
<td>Automotive sub-systems</td>
<td>Service development &amp; planning</td>
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<tr>
<td>Sector / product</td>
<td>Focus / aims</td>
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<tr>
<td>Power transmission</td>
<td>Business opportunities for new technology</td>
</tr>
<tr>
<td>Railway infrastructure (3 applications)</td>
<td>Capital investment planning and technology insertion</td>
</tr>
<tr>
<td>National security infrastructure</td>
<td>Research program planning</td>
</tr>
<tr>
<td>Building environmental controls</td>
<td>New product / service opportunity; business reconfiguration</td>
</tr>
<tr>
<td>Road transport</td>
<td>Defining national research agenda; network development</td>
</tr>
<tr>
<td>Technical consulting (6 applications)</td>
<td>New service development</td>
</tr>
<tr>
<td>Automotive / aerospace</td>
<td>Corporate synergy</td>
</tr>
<tr>
<td>Academic (2 applications)</td>
<td>Strategic planning</td>
</tr>
<tr>
<td>Bio-catalysis</td>
<td>Research planning; network development</td>
</tr>
<tr>
<td>Satellite navigation</td>
<td>Research planning; network development</td>
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<tr>
<td>Food processing</td>
<td>Research planning; network development</td>
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<tr>
<td>Pneumatic systems</td>
<td>Innovation strategy</td>
</tr>
<tr>
<td>Emerging technologies</td>
<td>Research priorities</td>
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<tr>
<td>Automotive</td>
<td>Innovation opportunities</td>
</tr>
<tr>
<td>Retail (2 applications)</td>
<td>Business strategy and product planning</td>
</tr>
<tr>
<td>Off road vehicles</td>
<td>Global production strategy</td>
</tr>
</tbody>
</table>

**Standard process (integrated product-technology planning)**

The standard T-Plan process comprises four facilitated workshops – the first three focusing on the three key layers of the roadmap (market / business, product / service, and technology), with the final workshop bringing the layers together on a time-basis to construct the chart – see Fig. 6.
Fig. 6 - T-Plan: standard process steps, showing linked analysis grids

Also important are the parallel management activities, including planning and facilitation of workshops, process co-ordination, and follow-up actions. Simple linked analysis grids are used to identify and assess the relationships between the various layers and sub-layers in the roadmap.

Customising the process

Technology roadmapping is an inherently flexible technique, in terms of:

- The wide range of aims that roadmapping can contribute towards.
- The timeframe covered by the roadmap (past and future).
- The structure of the roadmap, in terms of layers and sub-layers, which can be adapted to fit the particular application.
- The process that is followed to develop and maintain the roadmap/s.
- The graphical format that is selected to present information and communicate the roadmap.
- The set of existing processes, tools and information sources in the firm, which the roadmap and roadmapping process need to integrate with.

Application of the T-Plan approach in a wide range of organizational and strategic contexts has enabled the flexibility of the roadmapping method to be explored. The approach can (and should) be customized to suit the particular application, in terms of roadmap architecture and the process for developing the roadmap.

The generalised roadmap shown in Fig. 7, based on observations of many roadmaps, illustrates the different layers and sub-layers that can be used to define the roadmap.
structure, which can be tailored to fit the particular context. The multi-layered generic architecture allows key aspects of knowledge about the business to be captured, structured and shared, strategic issues to be identified, and actions agreed. Alignment of ‘know-why’ (purpose), ‘know-what’ (delivery), ‘know-how’ (resources) and ‘know-when’ (time) allows a balance between market pull and technology push to be achieved.

**Figure 7:**

![Generalised technology roadmap architecture](image)

Customisation needs to be considered during the planning phase, at the heart of which is a design activity, where both the roadmap architecture and roadmapping process need to be considered in parallel. As with all design activities, the process is creative, iterative and non-linear in nature. The following checklist is used in T-Plan applications, as a basis for focusing discussion, which continues until the parties agree a plan that makes sense to all involved:

- **Context** – the nature of the issue that triggered interest in roadmapping needs to be explored and articulated, together with any constraints that will affect the approach adopted, including the following considerations:
  - Scope: defining the boundaries of the domain of interest (i.e. what is being considered, and what is not).
  - Focus: the focal issue that is driving the need to roadmap.
  - Aims: the set of goals and objectives that it is hoped to achieve with roadmapping, in the long- and short-term. As well as the overt business aims, organizational goals are also typically included, such as the desire to improve communication and to understand how the roadmapping approach can be used to support ongoing strategic activities in the firm.
  - Resources: the level of resource that the organization is willing to contribute, in terms of people, effort and money.
Technology Roadmapping

- **Architecture** – the structure of the roadmap, in terms of:
  - **Timeframe**: the chronological aspects of the roadmap (horizontal axis), in terms of the planning horizon and key milestones, and also whether past events and activities should be included.
  - **Layers**: the structure of the vertical axis of the roadmap, in terms of broad layers and sub-layers, which is closely related to how the business is structured and viewed (physically and conceptually).

- **Process** – the staged set of activities needed to build roadmap content, make decisions, identify and agree actions and maintain the roadmap in the future. The process includes a ‘macro’ level, in terms of the broad steps needed in the short-, medium- and long-term, as well as a ‘micro’ level, associated with the short-term and in particular the agenda that will guide the workshop/s.

- **Participants** – the people that need to be involved in the process and workshop/s, with the knowledge and expertise necessary to develop a well-founded and credible roadmap. Typically a multifunctional team is needed, representing both commercial and technical perspectives. The number of participants involved in the workshop/s depends on the specific context, and during the development and application of T-Plan workshop groups ranged in size from 5 to 35 participants. The agenda and facilitation approach adopted will vary depending on group size, with the need to break into sub-groups (with plenary feedback) if the group size exceeds about 10.

- **Workshop venue and scheduling** – a suitable date and venue is needed for the workshop/s, large enough to allow participatory roadmapping activity by the group/s.

- **Information sources** – it is important that the roadmapping activity takes account of available information, although there is a practical limit as to the quantity of data that can be accommodated in a workshop environment. Relevant information should be assessed prior to the workshop, and consideration given to what information should be supplied to participants prior to the workshop, handed out at the workshop, built into the roadmap template, or incorporated after the workshop in the context of an ongoing roadmapping process.

- **Preparatory work** – activities that need to be performed prior to the workshop/s need to be identified and agreed, such as inviting participants, booking an appropriate venue, preparing briefing documents and facilitation materials.

### Taking the 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 organisation.

While some organisations choose to use the 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 the market / commercial and technological knowledge in the organisation (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.

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

- **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.

- **Roll-out**: once the first roadmap is developed in an organisation, it may be desired to facilitate the adoption of the method in other parts of the organisation. 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 of the method where a potential fit with a business issue / problem is identified.

**Figure 8:**

Fig. 8 – Roadmaps integrate commercial and technological knowledge (EIRMA, 1997)

In either case senior management support is important, in terms of enthusiasm for use of the method, 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\textsuperscript{13}. Software that is developed to support roadmapping should aim to provide the following types of functions:

\begin{itemize}
  \item The multi-layer roadmap structure is recommended as the primary way of working with roadmapping data, owing to its simplicity and flexibility. Roadmapping objects (bars, linkages, annotations, etc.) can be defined in terms of their position in the layers, and on a time basis. The layered structure allows for a hierarchy of roadmaps to be developed, at any level of ‘granularity’ in the firm.
  \item Software should define a common architecture for building roadmaps in the firm, enabling data sharing and linkage, which requires specification of appropriate protocols and templates.
  \item The software should support management of the data that is associated with the roadmap, including data mining (‘drill-down’) and analysis, together with methods for managing the complexity of the data for the user (e.g. multiple perspectives on the data, critical paths, linkages, etc.). Inclusion of additional management ‘tools’, such as the analysis grids used in the T-Plan method and portfolio project selection matrices is desirable.
  \item The software should be as customisable as possible, in terms of setting up the layered structure, definition of roadmapping objects, choice of graphical representation, and inclusion of annotations, notes and supplementary information.
  \item One of the strengths of the roadmapping approach is its support for integration of information, processes and methods in the firm, and the supporting software should reflect this, proving facilities for importing and exporting data, together with linkages to other business and management information systems. In its broadest sense, the roadmapping process and supporting software can form a central element of knowledge and information management systems in the firm.
  \item The software should cater for both ‘novice’ and advanced users. The software should be able to ‘grow’ with the company as its use of roadmapping expands and matures. The software should provide support for the development of individual roadmaps, as well as support for enterprise-wide roadmapping (scalability). The software should support multi-user, distributed participation in the development of roadmaps, which require input from various perspectives in the firm. Roadmap elements should be dynamically linked (within roadmaps and between roadmaps), so that the effects of changes to roadmaps can be readily determined.
  \item Software should fit in with the human process that is a key benefit of the technique; the development of good roadmaps typically requires multifunctional workshops. There is scope for creative approaches to the development of effective software-user interfaces, such as the use of electronic whiteboard and brainstorming technology. The role of software is to support the roadmapping process, and users should not expect that software alone will result in good roadmaps.
\end{itemize}

\textbf{Case example - Foresight Vehicle technology roadmap}

An Internet search using the term “technology roadmap” will provide many examples of sector-level roadmaps, which are a useful resource for those embarking on a technology development strategy. Here are a couple of examples:

\begin{itemize}
  \item The authors are aware of two dedicated technology roadmapping software systems: Geneva Vision Strategist developed by The Learning Trust (an enterprise solution used by Motorola and other large organisations): http://www.learningtrust.com; and Graphical Modelling System (GMS) developed by the US Office of Naval Research (ONR): http://www.onr.navy.mil/gms/gms.asp
\end{itemize}

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A technology roadmapping initiative was undertaken in 2001-2 (Phaal, 2002) to stimulate the network (drawing in new members), with the specific aim of defining the research challenges for the next round of funding. The process, which resulted in publication of version 1.0 of the roadmap (available to download from the Foresight Vehicle web site), involved a total of 10 workshops over a period of 10 months, with more than 130 participants from 60 organisations. The technology roadmap architecture is shown in Fig. 9, and the roadmapping process is illustrated in Fig. 10.

A systems approach was adopted (see Fig. 11), recognising that the road vehicle forms part of a much larger system, which needs to account for the social, economic and environmental goals that form the three cornerstones of sustainable development, and reflecting the political, technological and infrastructural systems that can either enable or hinder progress towards these goals. These six themes ('STEEPI') were used to structure the top two layers of the roadmap, in terms of the trends and drivers, and also the road transport system. The technology layer of the roadmap was structured in terms of the five Technology Group areas that form the core activities of the Foresight Vehicle consortium (see Fig. 8).

Figure 9:

Fig. 9 - Foresight Vehicle technology roadmap architecture
The Foresight Vehicle technology roadmap is intended to act as a resource of the many different stakeholders involved in the network, including companies, universities and government. For this reason the report was written in such as to minimise bias and ‘interpretation’, presenting the information that had been gathered during workshops and subsequent Internet-based research in an objective fashion. A total of 28 ‘rich picture’ roadmaps form the core of the report (Appendices), associated with the various sub-layers of the roadmap, with the main body of the report comprising a successive series of higher level summaries of the detailed content in the appendices, including text, tables and simplified graphics. For these reasons it may be more appropriate to term this a technology ‘landscape’ rather than a ‘roadmap’. The approach adopted is illustrated in Fig. 12 and 13, showing one of the 28 ‘rich picture’ roadmaps (for the

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14 http://www.foresightvehicle.org.uk/
social trends and drivers theme), and also one of the summary graphical roadmaps (for the hybrid, electric and alternatively fuelled technology theme).
Figure 12:

Social trends and drivers ‘rich picture’ roadmap

- 80-85% of journeys by car (2010: 75%)
- 75% of all journeys are under 5 miles and 45% are less than 2 miles
- Nearly one-third of UK households do not have a car (13 million people)
- Many different stakeholder groups, with different needs from transport system
- UK car-centric culture
- 2002: 25% of UK population (40,000 deaths)
- 2010: Passenger numbers through UK airports increase by 50% by 2020
- Journey times increasing (2015: 20-50%)
- Vehicles sold increasingly as ‘lifestyle vehicles’
- Increasing female vehicle purchase / ownership (women are more likely to describe their cars as ‘stylish’, ‘sporty’ or ‘fun’)
- Balance between global, national and local solutions
- More than half of drivers exceed speed limits on motorways, dual carriageways and residential roads
- Increasing mobile telephone calling schemes and pedestrianisation of town centres
- Increase in passenger and freight transport in peak travel periods
- Journey times increasing (70% longer)
- More drivers use car for leisure day trips
- Demand to reduce deaths and injuries on roads
- Shift in social attitudes to spending
- More residential traffic calming schemes and pedestrianisation of town centres

Key: Mobility & congestion; Lifestyle & attitudes; Demographics; Health, safety & security

Fig. 12 – Social trends and drivers ‘rich picture’ roadmap

Figure 13:

Summary graphical roadmap for hybrid, electric and alternatively fuelled vehicle technology

- Vision: Sustainable vehicle fuel and engine systems, that meet the needs of society, industry and the environment
- Hybrid, electric and alternatively fuelled vehicle technology development, leading to new fuel and power systems, such as hydrogen and fuel cells, which satisfy future social, economic and environmental goals
- Continued improvement in terms of range, life, safety and performance
Summary

Technology roadmaps clearly have great potential for supporting the development and implementation of business, product and technology strategy, providing companies have the information, process and tools to produce them. The following general characteristics of technology roadmaps have been identified:

- 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. 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 roadmap having the potential to drive the strategic planning process.

- The generic roadmapping approach has great potential for supporting business strategy and planning beyond its product and technology planning origins. It should be recognised that it is not a ‘black box’ methodology, that each application is a learning experience, and that a flexible approach, adapted to the particular circumstances being considered.

- Roadmaps should be expressed in a graphical form, which is the most effective means of supporting communication. However, the graphical representation is a highly synthesised and condensed form, and the roadmap should be supported by appropriate documentation.

- Roadmaps should be multi-layered, reflecting the integration of technology, product and commercial perspectives in the firm. The roadmapping process provides a very effective means for supporting communication across functional boundaries in the organisation. 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-related dimensions in the business, such as ‘know-why’, ‘know-what’, ‘know-how’, ‘know-when’, ‘know-who’, and ‘know-where’.

- Roadmaps should explicitly show the time dimension, which is important for ensuring that technological, product, service, business and market developments are synchronised effectively. 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.

- 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.
Bibliography


