Towards visual strategy: an architectural framework for roadmapping

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Abstract

Roadmapping concepts and techniques have been widely adopted (and adapted) by many organizations, at product, technology, company, sector and policy levels, since its first application in the late 1970s to support integrated product-technology planning. The roadmapping approach is flexible and scalable, and can be customized to suit many different strategic and innovation contexts. However, this demands careful planning and design, including considerations of roadmap structure, process and participation.

This paper explores the issues of how to design and architect roadmaps and roadmapping processes, which is crucial if the approach is to provide a framework for supporting effective dialogue and communication within and between organizations. The structure of the roadmap, and the process for developing and maintaining the roadmap, should be designed to serve the purpose for which the activity is intended to satisfy, providing a 'common language and structure' for both development and deployment of strategy.

Introduction

Technology roadmapping, and its many derivatives, has become one of the most widely used management techniques for supporting innovation and strategy, at firm, sector and national levels. The roadmapping approach, the initial development of which is widely attributed to Motorola, more than 25 years ago, has been adopted (and adapted) by many organizations, initially within other large technology-intensive firms in the consumer electronics, aerospace and defense sectors [1, 2, 3, 4, 5].

A key benefit of the approach is the communication associated with the development and dissemination of roadmaps, particularly for aligning technology and commercial perspectives, balancing market 'pull' and technology 'push'. Roadmaps can take many forms, but the most general and flexible approach comprises a visual time-based, multi-layered chart, illustrated in Fig. 1, enabling the various functions and perspectives within an organization to be aligned, and providing a structured framework to address three key questions: Where do we want to go? Where are we now? and How can we get there?

The form of roadmap illustrated in Fig. 1 is very flexible, and the structure of the roadmap, and the process used to develop it, can be adapted to suit many different strategic and innovation contexts [7]. The roadmap framework can be considered as a dynamic business or systems framework, with the architecture of the roadmap providing a coherent and holistic structure (a common language) within which the development and evolution of the business or system and its components can be explored, mapped and communicated.

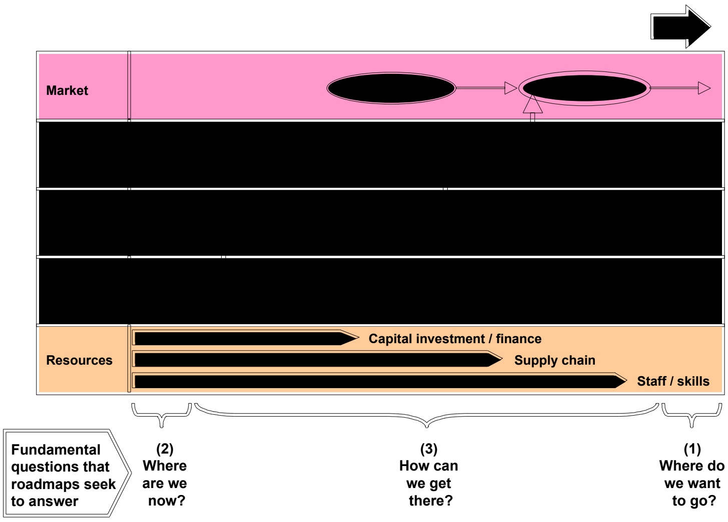

Fig. 1 – Schematic multi-layered roadmap, aligning functional strategies – adapted from [6]

This paper concerns structural aspects of roadmaps, together with the associated process of roadmapping, building on systems thinking. The power of roadmaps as strategic lenses through which organizations and complex systems can be viewed to support strategic planning is discussed, drawing on all key stakeholder perspectives. The principles of roadmap architecture and process design are described, and the various concepts are drawn together through consideration of the issue of 'granularity' as a key design parameter.

The proposed architectural framework is based principally on extensive practical experience of the authors over the past decade in supporting the development of roadmaps in a wide variety of industrial and business contexts (for example [7-12]). The aim is to make a contribution to the conceptual foundations of the technique, to stimulate further research.

Roadmaps as strategic lenses

The condensed visual format of a roadmap is important, providing a 'one-page' high-level view of the system in question, incorporating all key perspectives in a form that supports the strategic dialogue necessary for developing consensus and aligning action. This kind of roadmap can be thought of as a general-purpose 'strategic lens', through which a complex system (such as a business) can be viewed. The purpose of this lens is to structure and represent multiple interrelated perspectives on the evolution of the system, providing a framework to support understanding and dialogue. The roadmap lens is comprised of two distinct layers:

1. An underlying information-based structure (the roadmap architecture) – how the

information contained within the roadmap is organized, which represents the key elements of the systems (layers and sub-layers of the roadmap), set against time.
2. An overlaying graphical layer, with form, style and color chosen to represent the roadmap structure and its contents for communication purposes. While the multi-layered time-based format is the most comprehensive and flexible format for developing roadmaps, many different graphical styles have been developed [8].

The focus of this paper is on the structure (architecture) of roadmaps, rather than graphical style, where further work is needed to understand which formats are best suited to which purpose.

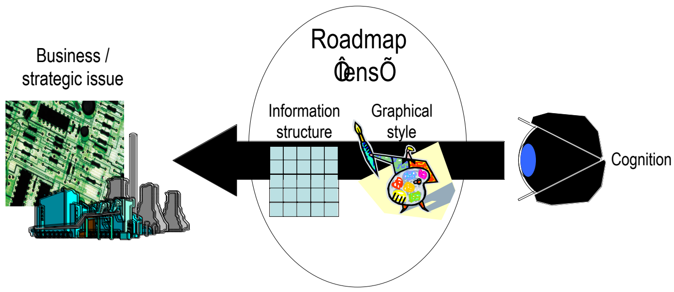

Fig. 2 – Roadmaps provide a strategic lens through which complex systems can be viewed

Roadmapping is a very flexible approach, which typically needs to be customized to address the specific system or subject in question. Roadmapping can and has been applied to many different subjects, focusing for example on technology, products, programs, industrial sectors and fields of science.

Roadmaps can cover a tremendous dynamic range. For example, Fig. 3 shows that a sector roadmap can be viewed at the level of a limited set of sector trends (order of magnitude 10^1), with the goal of relating these trends to relevant mono-disciplinary technology developments. Hundreds of systems may play a role in the sector, with the behavior of a single complex system determined by millions of details (order of magnitude 10^7). The challenge is to find the most relevant technology details in relation to the sector trend. The scientific foundation of the technologies used in the systems may be orders of magnitude more detailed again. Nevertheless, the purpose of a roadmap is often to align scientific efforts with the sector trends. Roadmaps provide a means for addressing this complexity.

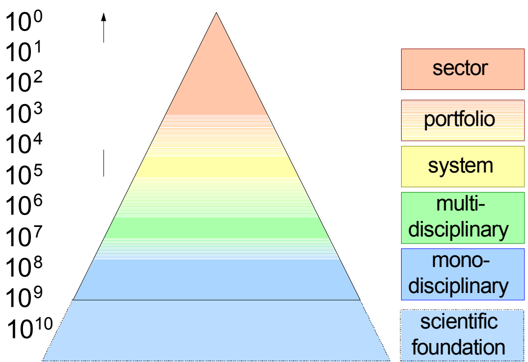

Fig. 3 – Abstraction hierarchy – the 'dynamic range' that can be covered by a roadmap is tremendous

When designing a roadmap architecture and process, a key initial step is to understand the strategic context, in terms of focus, scope and aims, together with identifying which perspectives are critical for understanding the system dynamics, defining goals, exploring strategic options and implementing change.

The development of good roadmaps requires the involvement of key stakeholders and groups, often representing very different perspectives. The subject of the roadmap (e.g. a technological product) is researched, explored or realized by organized groups of people, such as engineers or scientists, and then used by other groups of people, such as senior management to make decisions, or customers who purchase products in the market. Subject, creation and usage contexts provide different perspectives for the roadmap (Fig. 3), and the stakeholders representing these perspectives have different concerns: for example value and usability for users, skills and competences for creation, and feasibility and challenges for the subject itself (e.g. technical risks to overcome).

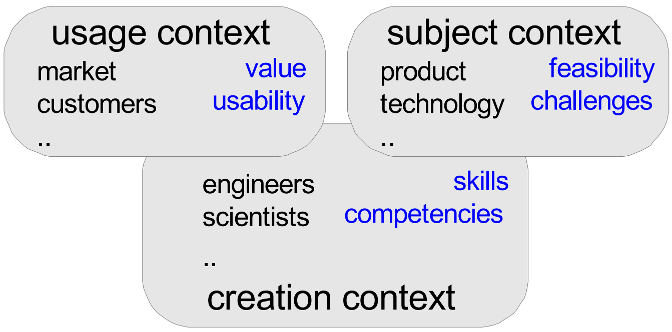

Fig. 4 – Different perspectives and stakeholders

Architecting a roadmapping system

Architecting roadmaps

As highlighted in Fig. 3, roadmaps can apply at various levels of granularity, focusing on anything from components of complex systems, to entire sectors or fields or science. The architecture (structure) of the roadmap must be configured to suit the focus and scope of the issue being addressed, to provide a framework and common language to support the dialogue necessary to develop and implement the desired innovation, strategy or policy. The roadmap architecture is comprised of two key dimensions:

1. Timeframes (typically the horizontal axis), which may include the past, short-, medium- and long-term perspectives, as well as aspirations / vision.
2. Layers and sub-layers (typically the vertical axis), represented by a systems-based hierarchical taxonomy, which allows different levels of detail to be addressed, illustrated in Fig. 5. This enables a family of roadmaps to be developed, spanning different levels of granularity. The strategic lens provided by the roadmap can ‘magnify’ and focus on the issues and areas of the system of most importance.

While linkages between specific elements of a roadmap can be readily shown in a roadmap, the fundamental causal relationships between the layers are not easily depicted. ‘Linked analysis grids’ are often used to understand and discuss these relationships, in terms of both market pull and technology push, as shown in Fig. 6. The structure of these grids, which span the broad layers of the roadmap, is based on the same hierarchical taxonomy as the roadmap itself, and hence the two frameworks fit well together.

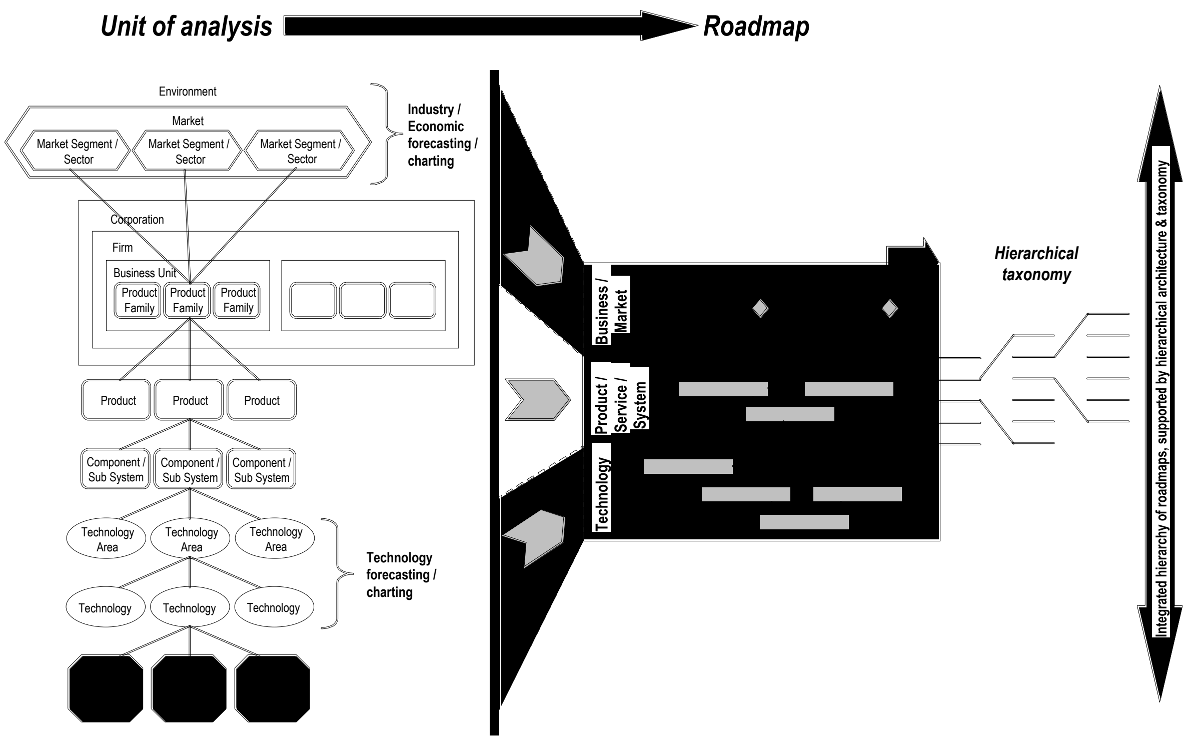

Fig. 5 – An hierarchical taxonomy underpins the roadmap architecture

Linked analysis grids can be used in various ways: ranging from supporting the identification and discussion of the general requirements and capabilities needed or offered (i.e. market pull vs. technology push), to scoring and prioritizing the relative potential of possible product or technology solutions to address a stated customer requirement or market driver (see for example [13] and the QFD method: www.qfdi.org).

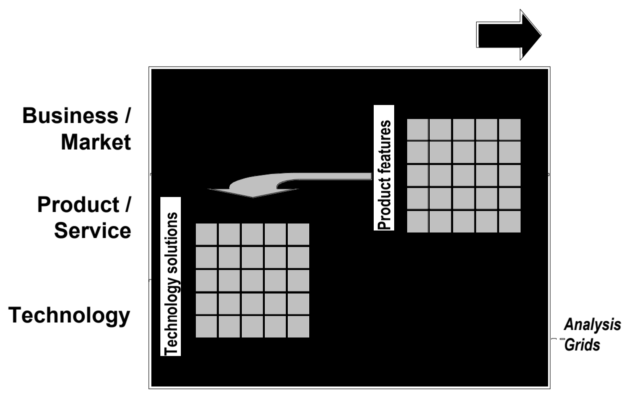

Fig. 6 – Linked analysis grids help to understand the relationships between roadmap layers and sub-layers

The following guidelines can be used to support the design of roadmap architectures, illustrated by the example shown in Fig. 7.

Timeframes:

The timeframe that should be represented on the roadmap depends on the rate of change to which the business or system is subjected. In fast-moving sectors, such as software or electronics, the time frame will be shorter, while for aerospace systems or infrastructure the time horizon will be much longer. Extremes that have been observed range from 2-3 year horizons for software companies, to 100 years for long-range energy futures. However, for many firms a time horizon of about 10 years is appropriate, in terms of representing the longer term trends and drivers that affect industry, together with the time that it can take to develop and commercialize new technology. It is recommended that five broad time horizons be included in roadmaps:

1) The past: often companies are reluctant to include this, preferring to focus on the future, but it is helpful to include the past in order to draw out key influences and events that have led to the current situation, and to highlight learning points that will influence the success of future plans.
2) Short-term: typically this might be a one-year horizon. This part of the roadmap is the most important output, as it will be transformed into tangible plans and actions that will be committed to (the only reason for considering the future and past is to agree what needs to be done next). This timeframe can be considered as the 'budget horizon', since resources will need to be committed to enable actions to be fulfilled.
3) Medium-term: typically this might be a three-year timeframe, linked to the strategic planning horizon, highlighting the broader direction and options that influence the short-term decisions and plans.
4) Long-term: typically this might be a ten-year timeframe, providing a bridge between the medium-term strategy and the vision or aspirations of the organization, enabling key uncertainties and scenarios to be articulated, and long-term shifts in the business and market environment to be explored, providing a 'radar' to capture and assess longer-term issues that affect current decisions and plans (e.g. research).
5) Vision: it is important to know where you are going (one of the three fundamental questions highlighted in Fig. 1). It is useful to set out the long-term aspirations of the organization, including its mission, providing a 'beacon' to head towards. Often, these aspirations can then be translated into firmer, quantified goals, targets and milestones in the short-, medium- and long-term, creating 'stepping stones' that lead from the current situation to the desired future state.

Layers:

In general, roadmaps comprise three broad layers:

1) The top layer relates to the trends and drivers that govern the overall goals or 'purpose' associated with the roadmapping activity, including external market and industry trends and drivers (social, technological, environmental, economic, political and infrastructural), and internal business trends and drivers, milestones, objectives and constraints. Collectively, the type of information contained in the top layer can be thought of as representing the 'know-why' dimension of knowledge.
2) The middle layer generally relates to the tangible systems that need to be developed to respond to the trends and drivers (top) layer. Frequently this relates directly to the evolution of products (functions, features and performance), but the middle layer can also represent the development of services, infrastructure or other mechanisms for integrating technology, capabilities, knowledge and resources in a way that delivers benefits to customers and other stakeholders (and hence value to the business), such as engineering systems and organizational capabilities. Collectively, the type of information contained in the middle layer can be thought of as representing the 'know-what' dimension of knowledge.
3) The bottom layer relates to the resources that need to be marshaled to develop the required products, services and systems, including knowledge-based resources, such as technology, skills and competences and other resources such as finance, partnerships and

facilities. Collectively, the type of information contained in the bottom layer can be thought of as representing the 'know-how' dimension of knowledge.

Usually an hierarchical structure (taxonomy) is appropriate – see Fig. 5. If more than one roadmap is to be developed, across an organization, then the architecture needs to reflect this. This will enable roadmaps to be linked and combined ('rolled up') to form higher level views (e.g. corporate roadmaps sit above business unit roadmaps), and also for 'drilling down' to create more detailed views (e.g. product-level roadmaps sit below business unit roadmaps). Sub-layers can be combined ('collapsed') and expanded to reflect the particular focus of a roadmap, within the structure provided by the hierarchical taxonomy, allowing the roadmapping 'lens' to focus on and 'magnify' the most important issues and parts of the system.

There are many possible ways of structuring the layers and sub-layers; there is no unique or necessarily best way of doing this, but achieving a good result is critical to the success of the activity. Often a number of possible strategies for the roadmap architecture are identified, with a need to define one primary view that will be incorporated into the structure. Usually, the other views are also important, and should be used as part of the process to define content of the roadmap. For example, for a family of products it would be possible to define layers in terms of the product family members, or the range of functions and performance measures associated with the products. If the product family view is select for the sub-layers, then within each layer (for each product family member) the evolution of function and performance would be charted within the layers.

Layers and sub-layers should, if possible, be compatible with organizational structures and 'language', such as market segments, product architecture and research groups. However, existing groupings are not always the most logical from a roadmapping perspective, so they should not be used blindly, and sometimes it is desirable to use a structure that cuts across existing structures, to encourage new ways of thinking.

It is important to define the architecture to the right level of granularity. Too much detail can be a mistake (i.e. too many layers and sub-layers), as the architecture can be too complicated and may constrain participants' thinking. On the other hand, too little detail makes organizing information that is captured difficult. Typically, a maximum of 5-8 sub-layers is desirable for any particular layer.

For product-level roadmaps a good starting point is to consider the various functions that the product performs (or might need to perform) and the qualities (e.g. performance and reliability) that have to be achieved. This encourages the separation of product from technology thinking – often, technology issues 'contaminate' the product layer, limiting options by creating an assumption that a particular technology is the only solution. Focusing on functions and qualities emphasizes user requirements, and opens up thinking about possible solutions and technologies that could provide the required functionality and performance, including future developments.

Generally, a layering strategy should be adopted that results in a high degree of 'de-coupling' between layers, and the layers should be clearly differentiated from each other. 'Evolution' over time should be able to be charted within each layer, providing a 'route' to the future. If a roadmap tells a 'story' then each layer or sub-layer represents a 'chapter'.

As well as the broad layers (e.g. market, product and technology), it can be desirable to include intermediate layers between them, to highlight key enablers and barriers required for bridging these layers, where action is required. For example, theoretical barriers must be overcome for science to be utilized in technology; technical barriers must be overcome for technology to be implemented in products; non-technical barriers (commercial and organizational) must be overcome for products to succeed in markets.

Fig. 7 – Example roadmap architecture

The best way to judge if the structure (layers) of the roadmap is appropriate is to test it (does it 'work'?). 'Thought experiments' are helpful, to think through the ‘logic’ implied by the roadmap structure. It should be possible to imagine how each theme will evolve (for each layer and sub-layer), and also how the layers relate to each other, in terms of pull (requirements, from top right to bottom left of the roadmap) and push (capabilities, from bottom left to top right). Pick a specific issue (a market opportunity and/or key technology) and think through this, articulating the associated ‘narrative thread’. For example: “Key trends A, B and C will create a market opportunity D in the medium term and E in the long term, which will require the development of product F and service G, together with manufacturing system H, which means that we will need to invest in technology I and develop a strategic partnership with J”.

Think about how much space (‘real estate’) is required for each part of the roadmap (layers and sub-layers, and timeframes). This should reflect both the likely density of information, and the relative importance of each area (depending on context, scope, focus, aims and priorities).

Architecting roadmapping

It is often said that the process of developing a roadmap is more valuable than the roadmap itself, because of the associated communication and consensus generated between functions and organizations. It is important to understand the nature of the roadmapping process, and how this relates to other business processes in the organization (typically strategic planning and innovation or new product introduction in firms). Roadmapping should integrate with and support these processes if it is to have a sustainable impact.

With reference to Fig. 3 and 4, a roadmap is created in multiple iterations over the views and abstraction levels. The first iteration is done in a short time-span: one or a few days. Subsequent iterations require some more time: from a few days to a few weeks. The iterations ensure feedback between the *why*, *what* and *how* perspectives. Fig. 8 shows the resulting process funnel, indicating the increasing focus during the roadmap creation.

Each iteration progresses through the same four phases, as shown in Fig. 9. In the ideation phase the structure and the type of information of the roadmap is 'designed', the scope is determined and the roadmap space is populated with existing ideas. The divergence phase is used for further exploration, for instance by creating scenarios, fact-finding and brainstorming to identify opportunities. The convergence phase is used to analyze the resulting 'playing field' and to reduce the content to the essential trends, risks, opportunities, design/technology issues and competence questions. A smaller team synthesizes and consolidates this information in a more comprehensive set of visualizations, which can be packaged differently for the specific audiences, such as sales, management or engineering.

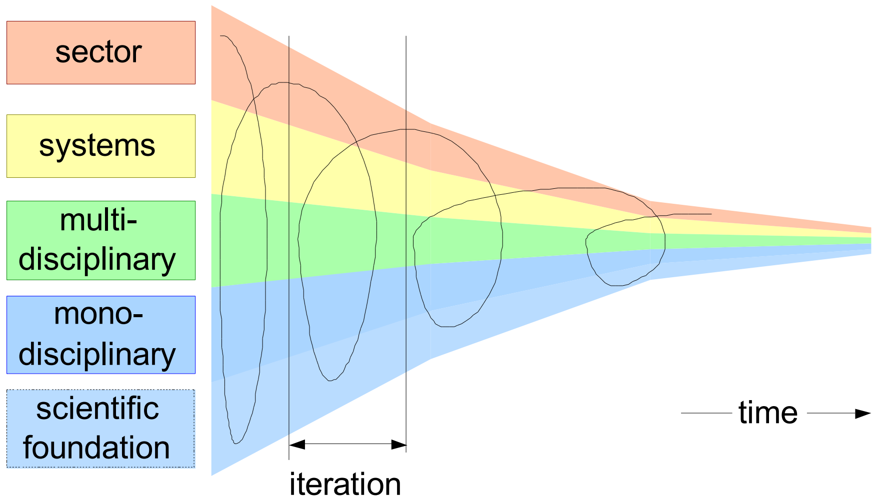

Fig. 8 – Narrowing scope in short iterations; early iterations are very short (days), later iterations may take weeks

Granularity as a key perspective

During the iterative phases of the roadmapping process, several artifacts (roadmaps) emerge with differing amounts of structuring and differing amounts of information. Fig. 10 shows the amount of information and structure that is typically appropriate per artifact, as well as the iteration and synthesis order.

The expert view contains lots of information, but not yet a great deal of structure. The amount of structure in the expert view can be limited due to the specialist nature of the expertise, as such a view is more homogenous and shows many relevant facts and trends for the expert. Expert views are typically created by 1 to 5 persons per view, spending a few weeks of effort per month, over a period of a few months.

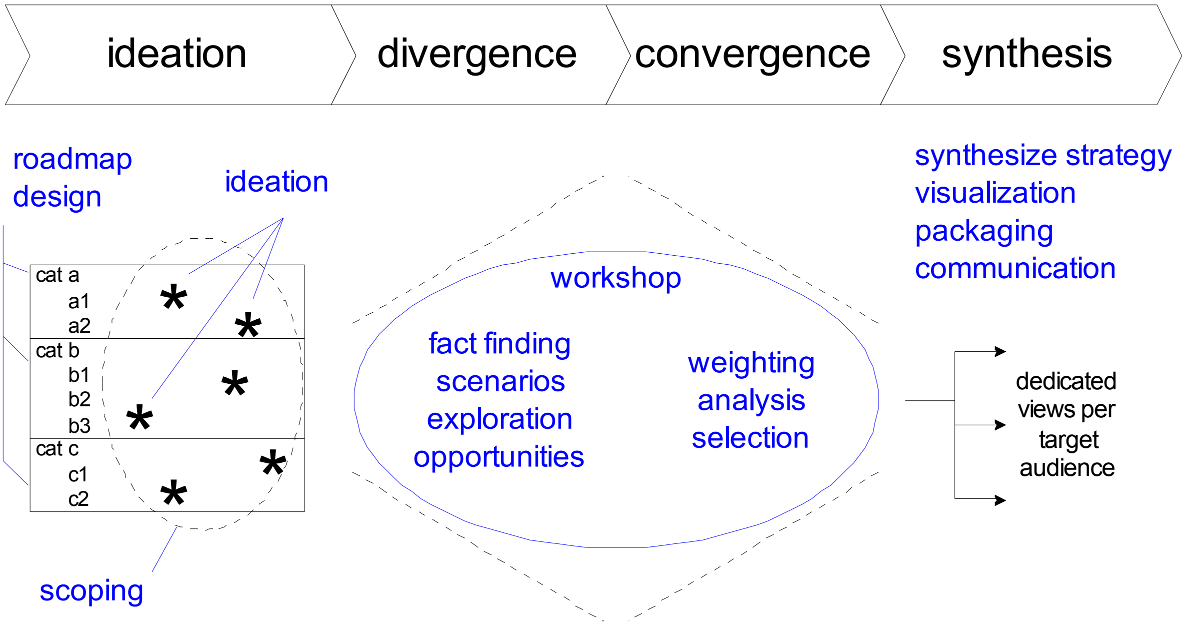

Fig. 9 – Phased approach per iteration

The expert views are integrated in a one-page detailed roadmap. The heterogeneous nature of such a roadmap may result in much more structure (periods in columns, subject and aspect areas, relations and threads). At the same time the amount of information has to be reduced. More than 50 information items creates an overcrowded diagram, where the audience drowns in an overload of information. The one page detailed roadmap is generally the result of a few broad workshops with 8 to 30 participants. These workshops typical require a few days of effort over a period of a few weeks.

The synthesis of the workshop information is done by a much smaller team, spending a few days of effort over a period of a few weeks. The result of the synthesis is a condensation into essentials: a one page strategic roadmap. This one page roadmap contains 1 to 6 main messages, relating *why*, *what*, *how* and *when*. Both structure and the selection of information items are focused on supporting and explaining these messages. Too much information and structure would distract from the message. Too much structure makes the roadmap too rigid; structure starts to dominate the purpose. Too little structure or too little information results in a superficial roadmap.

From the strategic roadmap several directed target views can be derived, for instance for marketing and sales purposes or for higher management. These targeted views typically have a limited amount of information. For example, a target view can be a product roadmap showing the improved performance/price ratio over time for specific systems.

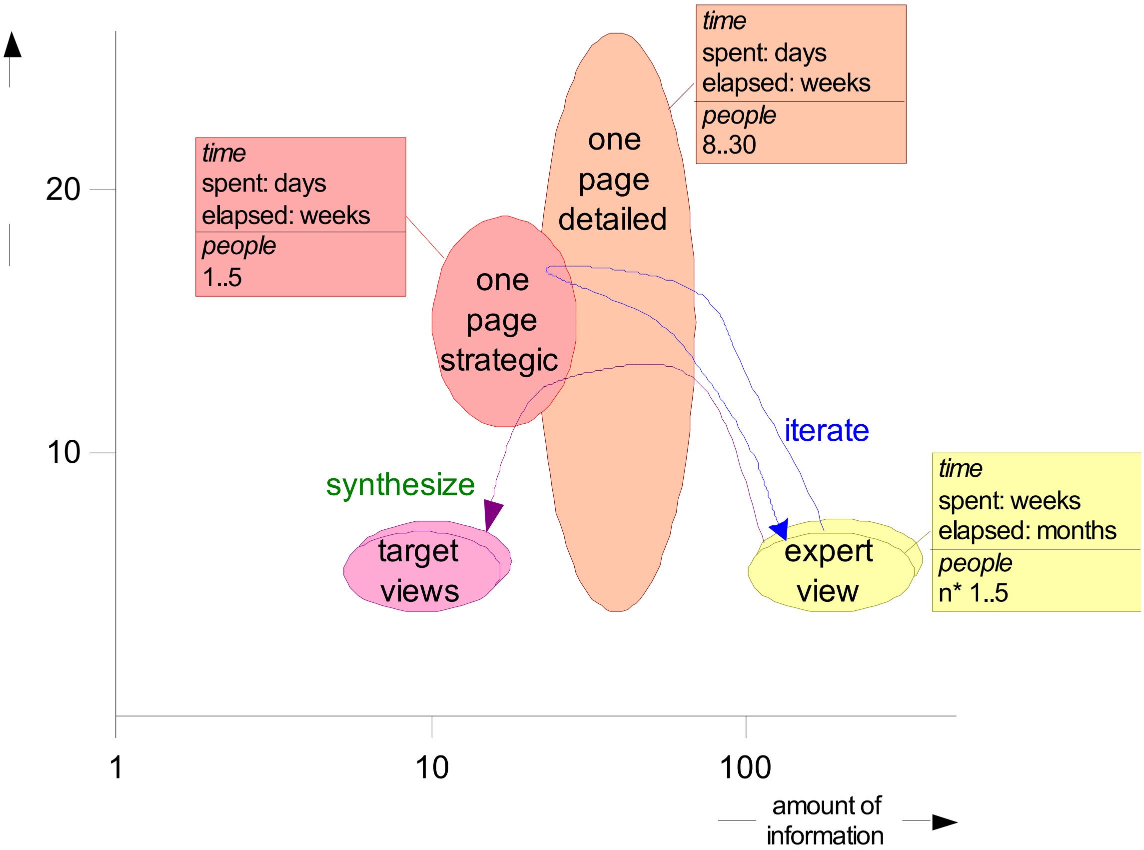

Fig. 10 – Desired amount of information and structure for the different roadmap artifacts

Strategy (roadmapping) as a core competence

Strategic planning is a vital process in any organization if it is to achieve sustained competitive performance. Roadmapping, which uses simple visual frameworks to support the dialogue and communication necessary to develop and deploy strategy, is a key supporting technique. Thus, strategy (and roadmapping) can be considered to be a core competence that organizations should spend time and resources improving. Organizations need to experiment and learn.

The use of simple and 'light' frameworks and processes is desirable, where appropriate, as this encourages a flexible and responsive strategic planning process that can adapt to changes in the external and internal environment, facilitating a rapid process cycle time that enables learning and improvement. Natural tendencies to over-complicate and bureaucratize the process should be resisted, as this will make the process difficult to sustain, and the roadmaps burdensome to update.

Organizations implement roadmapping in many different ways, including 'top-down' and 'bottom-up' approaches. The following 'bottom-up' pattern has been observed in many large firms, and can enable the learning aspects associated with the development of well-founded roadmapping systems:

- Exploratory phase, where 'pockets' of roadmapping activity emerge to satisfy local requirements. Often these 'early adopters' are not aware of each other, and the approaches vary considerably. This experimentation is healthy, as roadmapping generally needs to be adapted to suit the particular organization and application context.

- As roadmapping methods are used more, the activity becomes more visible to senior managers, since a key output from any roadmapping activity is strategic communication. A sensible step at this stage is to form a community of practice, to share experience and to develop common approaches, architectures and graphical elements, where appropriate.
- Once a sufficient critical mass is achieved, or the process and its benefits are sufficiently visible and proven, roadmapping may be integrated as part of the core business processes, such as within the annual strategic planning or budget allocation processes, or as part of stage gates in the innovation or new product introduction processes.

At this stage the use of enterprise software solutions can be considered, which has the advantage of potentially linking together roadmaps in a large distributed organization. However, the adoption of such systems should be treated with caution, as the main benefits of the technique lie in the dialogue and communication associated with their development. The use of simple one-page templates and graphical software, as part of core business processes, supported by a community of practice, is a viable alternative.

A key success factor for roadmapping is ownership by specific individuals of the artifacts (roadmaps). The one page strategic roadmap is often owned and edited by a system architect. Fig. 11 shows the typical growth path of a system architect, highlighting the prerequisite knowledge and experience of system architects. A challenging question is: how to educate such people in preparation for roadmapping?

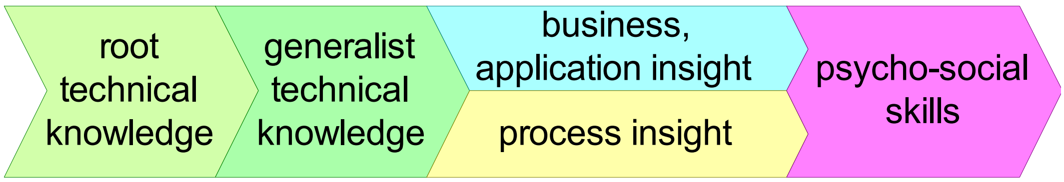

Fig. 11 – Typical growth path of system architects

The Embedded Systems Institute at the University of Eindhoven provides a curriculum for system architects, as shown in Fig. 12. The foundation is one of the conventional curricula for engineering or science. The next step is to broaden the candidates experience by providing multi-disciplinary methods and techniques focusing on the design of a single system aspect, for example performance, reliability or evolvability. A course on Modeling and Analysis (MA) teaches the more generic capability needed in systems architecting and design. The course Multi-Objective system Architecting and Design (MOSAD) integrates these single aspects into a complete system that needs to fit in the customer context and needs. The Systems Architecting course (SARCH) addresses the non-technical aspects of architecting, such as business, application, market, organization and processes (see [14] for architecting capabilities). Roadmapping is one of the modules in SARCH, building on all underlying courses. SARCH course participants have indicated that roadmapping is the most used method of those covered in this course [10].

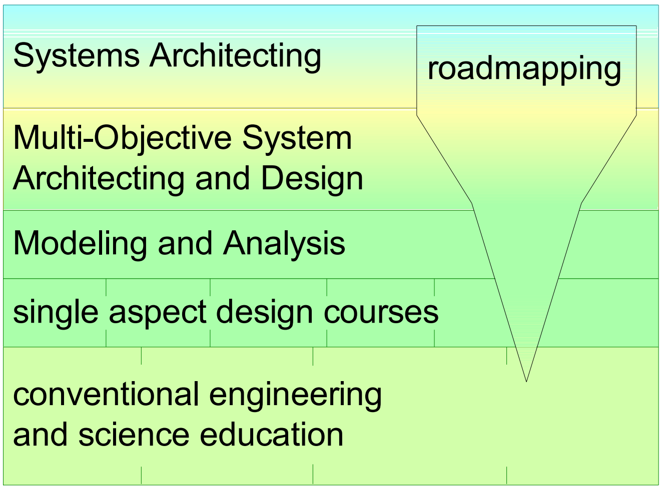

Fig. 12 – Roadmapping education superimposed on the System Architect Curriculum proposed by the Embedded Systems Institute

Conclusions and way forward

Roadmapping has become one of the most widely used methods for supporting integrated strategic planning, at both company and national levels. However, there has been a proliferation of approaches and frameworks, with little underpinning theory or conceptualization. This paper has sought to make a contribution towards this, focusing on the architectural aspects that are essential if roadmaps and the processes for developing roadmaps are to develop on a sound basis.

Further work is needed, linking practice, research and teaching. Interesting challenges and opportunities include:

- Understanding the 'visual language' of strategy and innovation. It is clear from the many examples of roadmaps that have been published that numerous visual forms and approaches are used, and the quality is variable. Yet the visual aspect of roadmaps is one of the main reasons why the method is so attractive. Guidance is needed on how best to use visual devices to support the development of roadmaps as effective aids for knowledge elicitation and communication.
- Workshops are an important aspect of most roadmapping processes, providing a forum for bringing together multiple stakeholders. New technologies are being developed that may revolutionize the human interaction needed to develop roadmaps, including collaborative workspaces, interactive displays and web-based collaborative technologies. Experimentation is needed to assess how best to use such technology, and to identify requirements for its enhancement.

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