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Topic Roadmapping and Performance Dimensions - guiding technology commercialisation

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Identifying problems that a technology can solve at an early stage in its development can enhance the exploitation opportunities for an organisation. Initiating an ongoing technology-commercial dialogue facilitates the process but can feel unstructured and lacking in focus. Current roadmapping processes, while supportive of the communication process, sometimes lack consideration of specific parameters needed for matching a new technology to a new market.

This paper describes the development and testing of a practical approach to mapping technology opportunities, with the aim of engaging both commercial and technical stakeholders in evaluating a technology and recording tangible outputs from the discussion. Using an exploratory topic roadmapping workshop approach in conjunction with a technology performance comparison template, a practical process is provided for scientists, technologists and industrialists to drive forward targeted commercialisation. Development and use of this approach is illustrated by case studies of the process and the templates used. The templates are easy to apply and help to structure and guide discussion, promote a consensual way forward and lead to practical action plans. The organisational impact and process learning is discussed, along with implications for improving and further testing of the methods.

1. Introduction

Identifying problems that a technology can solve at an early stage in its development can enhance the exploitation opportunities for an organisation. Initiating an ongoing technology-commercial dialogue facilitates this process but can feel unstructured and lacking in focus. Current roadmapping processes, while supportive of the communication process, sometimes lack consideration of specific parameters needed for matching a new technology to a new market.

This paper describes the development and testing of a practical approach to mapping technology opportunities, with the aim of engaging both commercial and technical stakeholders in evaluating a technology and recording tangible outputs from the discussion. An exploratory

topic roadmapping workshop approach is used in conjunction with a new technology performance comparison template. Together these techniques provide a practical workshop process for scientists, technologists and industrialists to drive forward targeted commercialisation.

The design and first use of the performance dimension template was part of a previous project¹ seeking to improve commercial-technical dialogue at an early stage of technology development.

The approach was selected for trial inclusion in the topic roadmapping process to help describe the functionality and performance characteristics of an application or research topic. The motivation for strengthening the analysis of the first step of the topic roadmapping was based on observations during topic

¹ STIM Consortium project 'Marketing process for technology' 2014.

roadmapping workshops:

- Participants often had difficulties in explaining / verbalising the real benefits of a particular technology
- Participants tended to “copy” existing applications in the market place, and assume that any new technology would automatically replace incumbent ones
- Participants tended to re-introduce existing technologies at the next step in the process regardless of whether they made any sense (or created a positive difference) from an application perspective
- The development of technologies discussed in the next step in the process sometimes were not directly linked to the product/application vision

Hence it was hoped that the inclusion of the performance dimension template would allow workshop participants to discuss and agree in more detail what is required from a development point of view, thus strengthening the roadmapping process and resultant actions.

Development and use of this approach are illustrated by case studies of the process and the templates used. The templates are easy to apply and help to structure and guide discussion, promote a consensual way forward and lead to practical action plans. The nature of the performance dimensions, the organisational impact and process learning/success are discussed, along with implications for improving and further testing of the approach.

2. Literature review

2.1 Technology commercialisation and the role of performance dimensions

There is a need for practical support in technology commercialisation (e.g. Gupta et al 1986; Maine & Ashby 2002; Dissel et al, 2009a; Huang et al 2016). The matching process (Maine & Garnsey 2004) between technology and market is a dynamic ‘balancing’ act. So breaking down a technology offering into several parts and considering how the importance of these parts may change for differing markets and/or applications is a useful exercise for structuring further development actions. In linking the technology to market drivers the push-pull dynamics were first considered in terms of linking layers in a product technology roadmap as shown in Figure 1 (Phaal et al. 2000) and in a more general sense within innovation overall (Herstatt and Lettl 2000).

The search for solutions to valid needs is facilitated by considering what ‘performance dimensions’ a technology can enable within an application space

before becoming concrete about a particular product, process or service. A practical tool for plotting such factors was found in Quality Management related work (e.g. Basu 2004) where ‘spider’ plots are used to compare levels of achievement before and after operational interventions. Hence the plots could be used to compare the performance of a new technology against existing technologies or their applications in defined markets, to see where the new technology has strengths and weaknesses. This adoption of a plotting technique commonly used in industry allows us to propose a performance comparison template for workshop use with performance providing a means of linking market, product/service and technology.

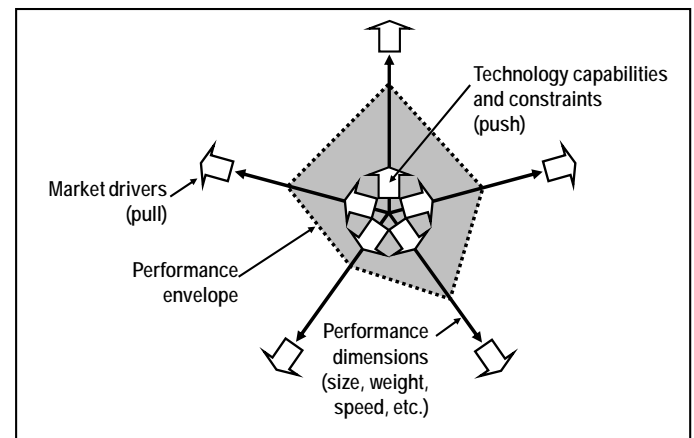


Figure 1. Push-Pull dynamics (Phaal et al, 2000)

2.2 Roadmapping for linking technology to market

Roadmapping is an established technique for visually linking technology and markets to company product, process and service development so that business decisions can be taken effectively. Various methods of roadmapping have been proposed, including the T-Plan and the S-Plan approaches, where T-Plan is technology-product roadmapping and S-Plan is strategic landscape level roadmapping (Phaal et al 2001; Phaal et al 2010). Another version is more open ended value roadmapping applications (Dissel et al 2009b).

Topic roadmapping was first used to explore specific opportunities that had been identified as worthy of further attention, following prioritisation either by dot voting on the S-Plan roadmap or by using a portfolio matrix (opportunity vs. feasibility). At its simplest, a topic roadmap has three horizontal ‘layers’, the middle one concerning the unit of analysis or problem under consideration, and a layer above with market drivers and needs and a layer below with specific technology developments required. A topic roadmap template can be either designed for each particular situation or a generic version (with guidance built-in) can be used.

3. Research methodology

3.1 Background

The approach taken is based on procedural action research (Platts 1993, Maslen & Lewis 1994, Neely et al 1996). The process was developed drawing upon literature and practice and then piloted in working organisations. Measurement of process success is an important element of this approach and the process is refined until stable and then tested more widely.

Process success is judged in response to three criteria: usability, usefulness and functionality. Usability means was the process easy to implement for both facilitator and participants. Functionality means does the process do what it was designed to do. Usefulness is evaluated by looking at organisational impact.

Organisational impact can be evaluated immediately from post workshop questionnaires and from the actions decided upon following the application of the ‘spider’ plot template. These actions are recorded on the topic roadmap. Further impact can be assessed by following up sometime after the workshop to see whether those actions have come to fruition, i.e. has the technology development been successful and the application commercialised.

3.2 The process

An established workshop-based topic roadmapping process was combined with a ‘spider’ plot template based on performance dimensions. This paper describes how the combined process was tested in six case study organisations as part of a wider roadmapping initiative (Table 1) resulting in 28 applications of the template.

Organisation	Problem addressed & times spider plot applied	
1.EPSRC Centre in innovative manufacturing	Identify applications that are emerging in engineering that would benefit from the technological advancements made by the research conducted by the centre	2
2.Academic-industrial consortium	Identify the performance parameters of the technology that are important for some priority applications and generate a list of focused research objectives in order to commercialise a new materials technology	6
3.Academic group	Align its research strategy to those of academic engineering colleagues and industrial partners	5
4.EU private-public ac-ind partnership	Support research, technological development and demonstration activities in a key technology in Europe to accelerate its market introduction.	7
5. Agricultural company	Seeking to develop collaborations with academic research groups to conceiving, developing and delivering new product offerings, innovation and improving manufacturing efficiency	3
6. Consumer goods company	Map the performance dimensions of selected products to align with the key technologies that will be important in product development.	5

Table 1: Case studies

The process builds on a customisable topic roadmapping template (see Fig 2) by using a ‘spider’ plot template (see Fig 3). The generic topic roadmap template has three layers: specification of the potential application and the required functionality that a technology can enable, the required technology developments, and enablers, barriers and risks. Guidance and prompts are incorporated into each layer of the roadmapping template, and the main three steps are shown.

The use of the ‘spider’ plot template to compare the new technology with incumbent technologies requires that the participants use a 1-5 Likert scale (1 denotes poor performance and 5 excellent performance) to score each technology on each performance dimension required for the application under consideration.

Application:				SUMMARY	
STEP 1: Scope and Future Vision	What's IN:	Required Functionality and performance			1. What is the Application?
	What's OUT:				
STEP 2: Roadmap for the Application	a. Milestones	Short term	Medium-term	Long-term	2a. What is the first Demonstrator? Actions?
	b. Required Technology/ Research				2b. Key Technologies / Research Required
STEP 3: Success Factors/ Knowledge Gaps					3. Key Enablers and Barriers

Figure 2. Topic roadmap template, showing steps 1-3 in process.

3.3 Key steps

Initially, Step 1 in the topic roadmap (Fig. 2) was discussed in groups. Each group explored one particular application or research topic and agreed on its scope, vision and desired functionality and performance parameters. When Step 1 was completed, each group was asked to transfer the key performance parameters of the application to the ‘spider’ plot template (Fig. 3) and assess the following in more detail:

- What are the required Performance Dimensions for a specific application?
- What is / would be the performance of this application using the new technology?
- What is / would be the performance of this

application incorporating a competitive or existing technology?

- d) Highlight specific areas for improvement where the new technology under-performs

The facilitator prompts for (a) that help enable participants to derive the Performance Dimensions are:

- What will you put in a sales brochure?
- What does it do (what value does it offer) for the customer?
- Think of aspects of process/product/service performance which are (or may be in future) important to the customer or business, and which the technology can deliver
- Example for a printer: size; speed; ease of use; reliability i.e. between technology and market, what you might use in a sales brochure.
- Consider both quantitative and qualitative dimensions
- Key dimensions are those that stand out as having high potential value to the customer or attractiveness to Company X.

Each of the six organisations carried out more than one 'spider' plot as part of their exploration of their chosen area (Table 1) and scored up to eight performance parameters on each chart (Fig 3). In each case, greater clarity was sought to make next step decisions on technology development and in some cases strategic collaboration.

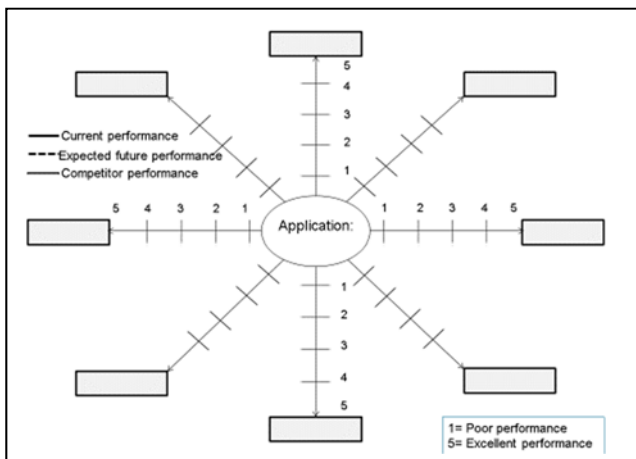


Figure 3. 'Spider' plot template, conducted between steps 1 & 2

After completion of the 'spider' plot, each group was asked to complete Step 2 in the topic roadmap (Fig. 2) and develop a technology plan for the areas where the performance gaps were the greatest. Finally, each group completed Step 3 and summarised key actions to take forward.

4. Results

The six cases were examined and then the twenty-eight 'spider' plots were reviewed to look for patterns, in terms of performance dimensions chosen, significance of performance gaps and types of actions decided upon.

4.1 Case example

The first case, an EPSRC Centre in innovative manufacturing, identified two very different possible applications that could benefit from their research – machines for Retail and Big Science projects. They defined performance dimensions for those two very different applications as summarised in Table 2.

Application identified from topic RM & prioritisation	Big Science projects	Retail machine
Spider plot comparison basis	New tech v main competitor's machine	Envisaged retail machine performance v current best tech
Performance dimension #1	Environmental isolation capability	Produce lighter product
Performance dimension #2	Throughput	<i>Installed cost, m/c life, service calls</i>
Performance dimension #3	Form accuracy	Produces very high spec product
Performance dimension #4	Surface finish	<i>Cost of machining each item</i>
Performance dimension #5	Multi-process	No need for or easy fill/clean lubricant
Performance dimension #6	Tool setting & registration	Self-calibrating, no expert set-up
Performance dimension #7	Energy usage	Target time to produce one item
Performance dimension #8	Physical footprint	Fully customisable to client need

Table 2. Case 1 Performance Dimensions.

The key performance *gaps* (in italics) identified for the Retail machine were the costs for producing the product as well as the expected acquisition and operating costs for the machine. It had clear **advantages** (in bold) of producing much higher spec, lighter, fully customised product more quickly than current alternatives.

For Big Science projects there were no major under-performance gaps between the new technology machine and the main competitor in this area. On the contrary, the potential new machine **outperformed** (in bold) the current alternative technologies in overall footprint, throughput, multi-process capability and environmental isolation capability.

In both cases the performance gaps combined with the knowledge gaps and enablers were used to plan the short, medium and long term actions on the topic roadmap, giving a clear plan for future development and commercialisation.

4.2 Performance parameters chosen

In terms of the performance dimensions chosen, up to eight parameters were allowed by the facilitator for each radar chart completed. In 10 out of 28 spider plots fewer parameters were needed.

Some categories transcended the nature of the technologies and applications being considered. For example, most spider plots had Cost as a performance dimension in some form, although in some cases this was represented by terms such as throughput, efficiency, longevity, affordability, yield, profitability, speed or value. Where the term Cost was specifically used, the categories included installed cost of a machine, material cost, manufacturing, production or machining cost, system cost, cost effect, operational costs or expenditure, capital expenditure and maintenance cost.

4.3 Performance gaps identified

The performance gaps revealed spanned the full range of possible categories from being mainly equal to or exceeding the necessary levels of performance or mainly underperforming.

For example in Case 2, concerning applications for a new material, in the first application considered there were no major performance gaps but in the second application it was found that there were gaps in performance on several key dimensions. So the Consortium could consider investing additional research effort to bridge these performance gaps, although it was likely that viable applications would probably only emerge in the long term. In a third application, it was apparent that the anticipated performance of the technology was likely to be inferior on all aspects to alternative technologies.

However, in Case 3, it was found that all key customer needs were covered by the five applications when taken together, but some further work was desirable in several disparate areas. In order to derive key research priorities for the research domain, participants summarised the most important research activities from the technology layer of each application roadmap. These were then individually ranked across all applications using scoring criteria from 0 to 3.

In Case 5, three applications were considered, two of which showed the expected current research project to provide over-performance on all areas and the third to lack only in possibly up to three out of eight performance dimensions.

4.4 Actions decided upon

There were concrete decisions made during the workshops based on the data revealed and discussed. In each case short, medium and long term actions were added to the developing roadmapping template as shown in Fig 2.

The spider plot is completed drawing upon on the information from Step 1 and in order to inform Step 2 on

the topic roadmap. Step 2a involves filling in key milestones for each time horizon and step 2b involves setting out the required technological research to reach these milestones.

In Case 4, for example, the markets were reasonably well defined in advance, being mainly in the automotive arena. The topic roadmaps were created for priority projects and the spider plots were used to assess how far the technology was from market requirements. One project had technology readiness level (TRL) targets in the short term of TRL 4, in the medium term of TRL 6 and in the long term of TRL 8. This resulted in 3-5 actions per time horizon for technologies at both component and system level.

In Case 6 the results were very varied across a set of innovation projects but this did not prompt the formation of new projects. Rather the spider plots were used to assess whether there were any generic functionalities required by multiple projects. The company operates in a modular product design environment and generic functionalities would inform standard product modules across product lines.

5. Discussion

What has been learned from the work in terms of defining performance dimensions, the organisational impact and process learning/success? An overview of possible areas to be considered in looking across the cases is summarised in the following sections.

5.1 Performance dimensions

The definition of performance dimensions rests upon desired functionality within an application space, not upon the technology specification or on the market directly. The number of performance dimensions needed to define an application environment appeared to vary between 5-8 but a top limit of 8 was imposed by the facilitator.

Looking across the cases for any common features did not reveal any strong patterns. Cost was well represented as might be expected but the other dimensions were application related.

How to derive a robust set of performance dimensions consistently in practice remains an issue, although facilitator prompts have been tested and appear to work well. The role of performance dimensions in mapping technology opportunities is of continuing interest, in terms of providing elements for meaningful comparison, as a step towards quantification or an accessible boundary object.

5.2 Organisational impact

The spider plots have had an impact on the case organisations in terms of the decisions made using the analytical detail they have revealed. This has included

decisions regarding strategy, funding and technological next steps.

Most of the impact achieved was due to the roadmapping work overall and only a small part was due to the contribution from the radar charts. The most direct indications of the impact of the spider plot template come from the actions decided upon following their application and recorded on the roadmaps.

In addition to what is recorded on the templates, verbal feedback, workshop questionnaires and following up after sometime after the workshop, are also useful. The evaluation of workshop questionnaires on two of the success criteria, usability and usefulness, indicates a good participant response to the process overall, that is including topic roadmapping, prioritisation, and the spider plot. No separate data is available for each part of the workshop (see 5.4 Process success for more detail).

Longer term follow up is necessary for true organisational impact from realised commercialisation of technologies considered, however in the shorter term other process indicators could be used, for example financial projections, continuation of research projects, additional collaborations or additional funding received.

5.3 Process learning

This research included the spider plot template as an intermediate step in the exploratory topic roadmapping process. The aim of this was to structure and facilitate the discussions necessary to complete stage 2 of the topic roadmapping process and to give focus to the next steps necessary to move towards technology commercialisation. Due to time pressures, the spider plot had to make a worthwhile contribution to be retained in the overall process. Positive feedback from the facilitator indicated that it had been a worthwhile addition:

“Until the spider plot was trialled in conjunction with the roadmapping, it was not realised that the priority technology development required followed logically from the biggest gaps in the performance characteristics. This added a lot of focus and strength in the technology development plan and a clear logic and narrative of why it was required. This also helped to reduce the inclusion of “pet” technologies or projects that can creep in during such activities”.

The combination of the topic roadmap and performance dimensions has proved to be powerful and has helped participants to:

- Understand and clarify the current and future performance requirements for a particular application and align technology developments where the gaps appear to be the largest.
- Avoid the introduction of “pet technology projects” or “latest technology hype” into the strategic / technology roadmap of the organisation.
- Reveal where the new technology can offer a distinct advantage and where it matches existing competitive technologies.

So it can be seen that the use of the spider plots within

the topic roadmapping process helped to derive well-informed action plans by giving a technique to combine key aspects of technology and market in application related performance elements, summarised directly onto the roadmaps.

5.4 Process success

Process success is considered against three criteria: usability, usefulness and functionality. Usability asks whether the process was easy to implement. Usefulness is evaluated by looking at organisational impact. Functionality looks at whether the process does what it was designed to do.

The post workshop questionnaires are largely positive and data on usability and usefulness has been extracted from these for Table 4. The questionnaires cover the whole process, so scores include roadmapping steps as well as the contribution from the radar chart. It can be seen that under each criterion there are two questions considered which both score generally well.

	Feedback question	Case 1 4 people	Case 2 9 people	Case 3 13 people	Case 4 24 people	Case 5 10 people	Case 6 9 people
U S A B I L I T Y	Structure and process of workshop	4.8	4	4.2	3.6	3.8	4
	Opportunity to participate & contribute	4.8	3.9	4.6	3.9	4.6	4.6
5 = excellent, 4 = very good, 3 = good, 2 = satisfactory, 1 = poor							
U S E F U L N E S S	Participation was worthwhile	4.5	4.2	4.5	4.2	4.4	4.2
	Useful insights obtained	4.8	4.4	4.5	4.2	4.3	4.3
5 = strongly agree, 4 = agree, 3 = no comment, 2 = disagree, 1 = strongly disagree							

Table 4: Post workshop feedback questionnaire scores

On functionality, verbal feedback from Cases 1 & 3 was very positive about the radar charts and how they specifically lead to well-founded action plans. The facilitator was also very happy with how the radar charts structured and provided strong evidence for the technology development plans needed for the topic roadmaps.

6. Conclusion

As we have seen, an additional template to complement roadmapping techniques has been tested in supporting the process of new technology commercialisation.

Further trials are currently being carried out however

preliminary indications are that the performance dimensions embodied in the spider plot template have proved to be effective as part of the topic roadmapping process by capturing the key improvements necessary for the adoption of any technology by a particular application and market sector.

This focuses further development, research and industrial collaborations. The template is easy to apply and helps to structure and guide discussion, promote a consensual way forward and lead to practical action plans.

The combination of the topic roadmap and performance dimensions templates has proved to be powerful and has helped participants to understand and clarify the current and future performance requirements for a particular application and align technology developments where the gaps appear to be the largest. In addition it has helped to avoid the introduction of favourite technology projects and the latest technology hype into the strategic technology roadmap of the organisation. Finally it has helped to reveal where the new technology can offer a distinct advantage and where it matches existing competitive technologies.

The implications for academics and practitioners are evident. This process helps practitioners looking for a time-effective way to determine the way forward in the commercialisation of new technology. The work also contributes to the wider understanding of roadmapping by exploring a mechanism to test and underpin data captured during the process. This supports the robust use of topic roadmaps for new single technologies within the wider portfolio in an organisation or for an academic spin-out or technology venture. The organisational impact and process learning have been discussed, along with implications for improving and further testing of the methods.

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