Using technology roadmaps with scenario analysis to manage risk and uncertainty

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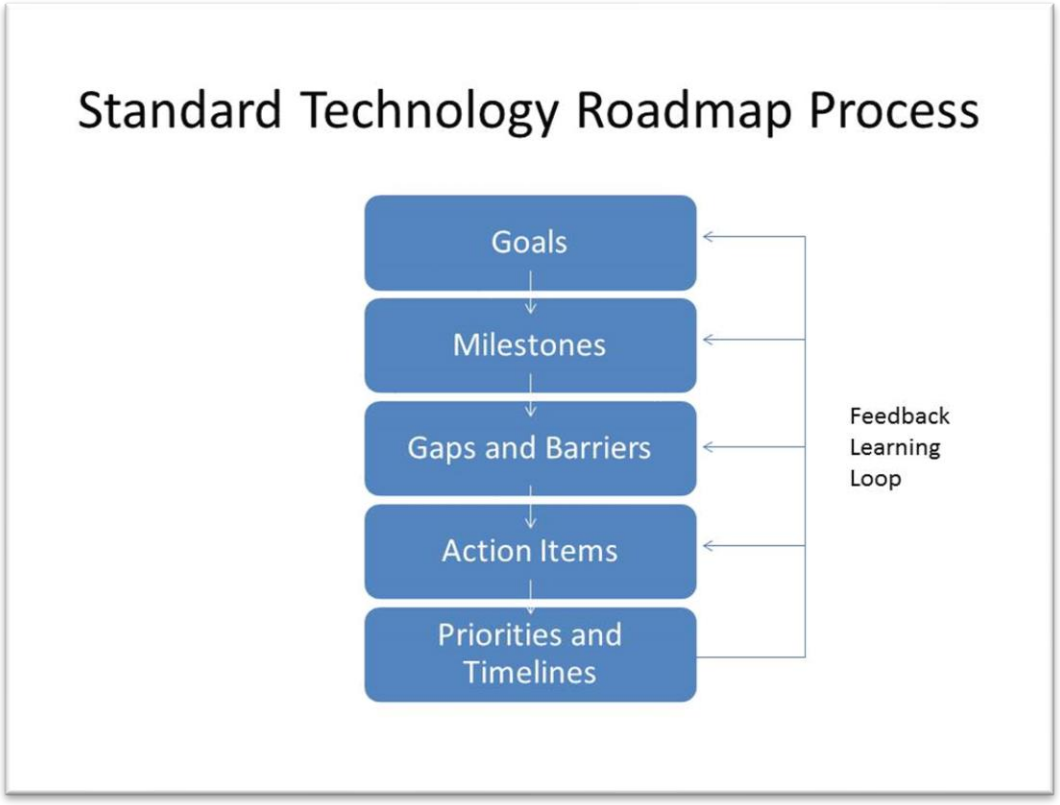
Technology roadmaps (TR) are a widely used tool for organizing and engaging a broad group of stakeholders in a collaborative process to address future technological uncertainties that might be pivotal in shaping an industry. The process of creating and sharing a technology roadmap allows participants to consider alternative ways technological and non-technological factors might work jointly to influence the future shape of an evolving market place or industry structure and the dynamics of each. Technology roadmaps for a wide range of industries, from semiconductors to energy, can be found on the web. As scenarios are a set of diverse narratives about how an uncertain future may unfold, they can be useful in getting more value from creating technology roadmaps by offering opportunities for options analysis, risk assessments and longer-term learning. This article will describe how this can be done.

In many TR projects the use of scenarios is limited to the early setting stages of creating a consensus around the initial goals of the TR process. But there are other uses of scenario analysis tools that can be applied within the TR process at both the industry and company level. Results from scenario analysis can be used in several steps of the TR process to expand the strategy development options and manage risks at both the industry and company level.

Exhibit 1 shows the standard steps in the TR process; this example is from the International Energy Agency in its 2014 Energy Technology Roadmap.[1] Scenarios are explicitly mentioned as a tool for use by the stakeholders in the stage of setting goals in the IEA work, afterward they are not used.

[1]See at www.iea.org/technologyroadmaps: As the IEA is followed on a global basis, this serves well as a typical example in industry of the use of technology roadmaps.

Exhibit 1



The early goal setting stage includes recruiting and organizing stakeholders, gathering information and alternative perspectives on the key issues at hand, early-stage research and scheduling get-acquainted meetings with key participants. This diverse set of stakeholders (or some subset, possibly supplemented by the onetime use of context experts) generally composes the group that is led by a facilitator to create the original set of scenarios. This way their ideas are included, there is an opportunity to build buy-in, and the group understands the core issues driving the scenarios.

Clearly sharing scenarios on the future of an industry at this goal-setting stage will help stakeholders focus on key questions and issues as well as generating alternative futures against which the goals can be evaluated and prioritized. A rigorous use of diverse and challenging scenarios at this stage of the TR process informs and challenges stakeholders and thus protects the project team from making a pivotal mistake of poorly selecting goals at the beginning. The scenario development at this stage also helps to set the context in which the group sees the evolution of the technology at stake. However, after the scenarios are used at this stage they are often then put on the shelf and the TR process becomes very focused on the milestones, gaps and barriers, all organized around a consensus viewpoint. This is understandable since much of the essential value of TR is isolating the improved performance needed at the technological level that might deliver value in the product or service sphere. Performance

improvement might mean lower cost, higher productivity or even a step change in innovation that makes new product and service features possible[2].

But after the goals are set and a consensus about the context of the technology is in place there is a chance that the TR process will become too narrowly focused. When this happens, the important alternate perspectives that the group considered at the beginning of the process are likely forgotten. Setting the scenarios aside at this early stage underutilizes the full suite of scenario analysis tools which can add value in the latter stages of the TR process. Those tools include:

1. Using the scenarios as spaces to create, evaluate and compare alternative options for actions (in particular investment options), known as wind-tunneling.
2. Using the scenario to set alternative variables in quantitative analyses of strategic options and investment analyses performed to manage risks.
3. Using the scenarios to create early warning indicators and plans for continuing research and longer-term learning.

How each of these can be done is described below. This work can be done at the group level or drawing from the work of the group further done on a proprietary level within a company.

Using the TR steps shown in Exhibit 1, Exhibit 2 summarizes ways scenario tools can be used more extensively at the both the industry and company levels. Technology roadmaps are often created by stakeholders from across an industry, however it is at the company level that investments are made that shift industries. Industries shift when companies make decisions that change the industry's competitive balance. Leading firms emerge from the competitive shift when they find and implement the combination of product or services that best incorporate technological innovation. Using the scenarios as described below can reduce the chances of the TR process being too narrowly focused and disconnected from uncertainty that remains in the business environment creating risks and opportunities in real time.

[2] For a look at the technological core of a technology roadmap see: http://www.nist.gov/itl/antd/cloud-102214.cfm links to volumes 1 and 2.

Exhibit 2

Technology Roadmap Stage	Scenario Uses and Benefits at the Industry Level	Scenario Uses and Benefits at the Company Level
Setting Goals	Find goals that work well across a range of diverse futures. Create scenario specific goals in support of the consensus goal.	Create company specific goals that vary by scenario. Assess key product/service goals that vary by scenario.
Creating Milestones	Test the consensus milestones against diverse scenarios to assess value. Expand the consensus milestone to meet alternative scenario conditions.	Test specific product/service milestones against alternative market conditions in the scenarios.
Isolating Gaps and Barriers	Use the alternative conditions in scenarios to wind-tunnel the importance of gaps and barriers.	Use the alternative conditions in the scenarios to wind-tunnel the importance of gaps and barriers within key product/service lines
Creating Action Items	Use the scenarios to generate alternative industry development paths and to set values for variables for quantitative analyses in alternative investment analyses and risk assessments supporting action items. Create and use early indicators to reset and prioritize action items.	Use scenarios to generate alternative investment options and to set values for variables in the company's proprietary investment and risk analyses for key product or services. Create and use scenario early indicators in the ongoing assessment of action items.
Setting Priorities and Timelines	Assess priorities and timelines within the alternative conditions in the scenarios as a final screen. Use early indicators to reset priorities and timelines.	Screen priorities and timelines for key products and services within the scenarios and early indicators to discern early mover advantages versus fast follower strategies.

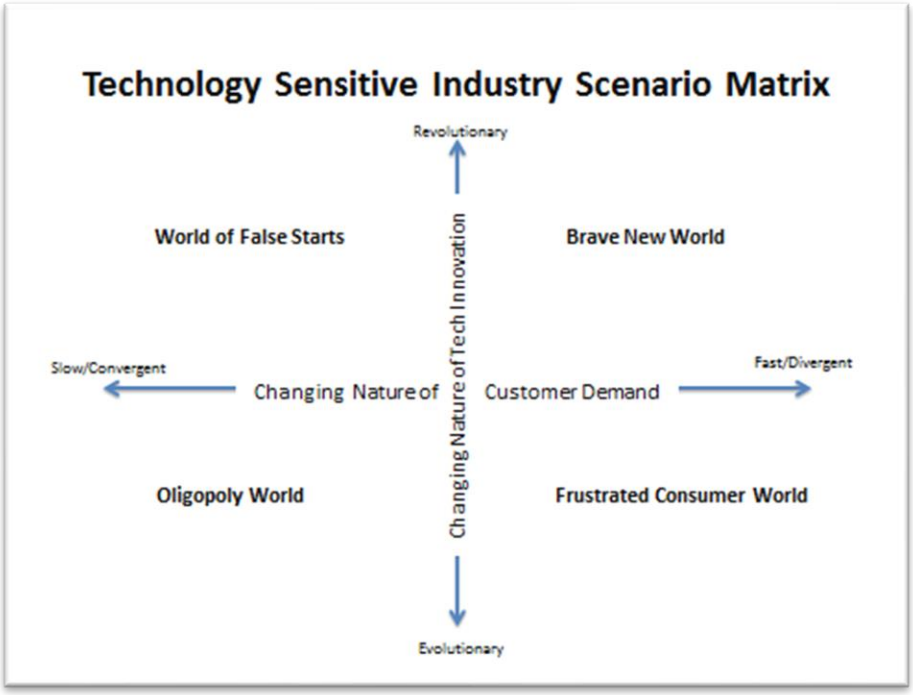
Using tools of scenarios to provide value in steps of TR

Generally, the central problem an industry faces when using TR is the uncertainty around the development and commercialization of a technology where there are diverse and competitive markets. In many cases the markets may be global and thus can be influenced by a wide range of economic, social, political, cultural and other non-strictly technological issues. A set of diverse scenarios are built from those same economic, social, political, cultural, technological and other factors that influence the marketplace. Often within the technology there may be pivotal and powerful options for the direction of investment and technological innovation at the industry level. There is a need for some shared understanding or logic to direct investments that needs to be generated and maintained by a consensus among key stakeholders that might even include governments for example, to support cloud computing the National Institute of Standards has instituted a TR process. Within a specific industry companies will have their own proprietary views and sense of their particular competitive positioning and market focus. Companies will thus have their own plans and strategies within the context of the industry's evolution.

Those plans and strategies will be subject to the same forces seeking to be understood through the use of the scenarios.

Exhibit 3 shows a scenario matrix that has emerged in various forms in projects where technology roadmaps were used. Such a framework emerges from a scenario development process in which a wide range of trends and drivers of change are discussed and analyzed by the relevant group. The matrix emerges once the group agrees on which drivers are most important and equally most uncertain in shaping the future environment. Since markets are the final determinants of the value of a technological innovation, market evolution often emerges as a central driver in scenario development. Clearly the pace and direction of technological innovation is also a highly uncertain and important driver. The long-term movement of technology from basic science with open applications to targeted science with targeted applications is uncertain and can shift at any moment.[3] These two central drivers are used to create a matrix from which four diverse and high-level scenarios can be further developed. The titles given to each scenario suggests a central idea around which the scenario narrative might be organized. Of course, full scenario narratives would include consideration of other drivers (political, social, cultural, economic factors and more) developed over an agreed timeframe.

Exhibit 3



The value of this framework is that it leads to very different worlds. In assessing the scenarios, I have witnessed stakeholders becoming overly attached to the North Eastern quadrant of the matrix, especially seeing the "Brave New World" as the assumed future. Goals in this world will typically have a lot of stretch in them. However, all the scenario worlds need to be considered. Comparing and contrasting of the results is where insights and new learning occurs. Pin-pointing three to four early indicators for each scenario are a vital step here. Early indicators might be in technology trends as well as government policy, consumer demands, or market dynamics. Monitoring the environment using early indicators is the essence of a real time learning loop back into the TR priorities and timelines.

[3] For a deep view of this see "Pasteur's Quadrant," by Donald Stokes. His work shows how basic science and applied research are related. See my Endnote discussion below.

As mentioned earlier, the core of technology roadmaps are the milestones, gap, barriers and timelines. A lot of time, expertise, discussion and debate are used in creating those key results. This is not easy work and in the process of reaching a consensus and a path forward that can be supported by the majority of the stakeholders, uncertainty can be suppressed. A lot of value can be gained here if the scenarios are brought back to expand the analyses of the roadmap and early indicators are identified to help set priorities and interpret developing events.

Exhibit 4 shows one way to present technology development areas (architectures). Those areas can relate or overlap in various ways. There might be a common core. Each area can have a distinct timeline related to developments needed from basic science and extending to pure technique in applications. Again, this is a complex product or industry-specific exercise. Creating timelines for anticipated evolution or breakthroughs in technology that deliver real value and innovation is difficult, but essential to the process. The full details behind Exhibit 4 generally fill up pages of documents depending on the industry and nature of the technology.

Exhibit 4

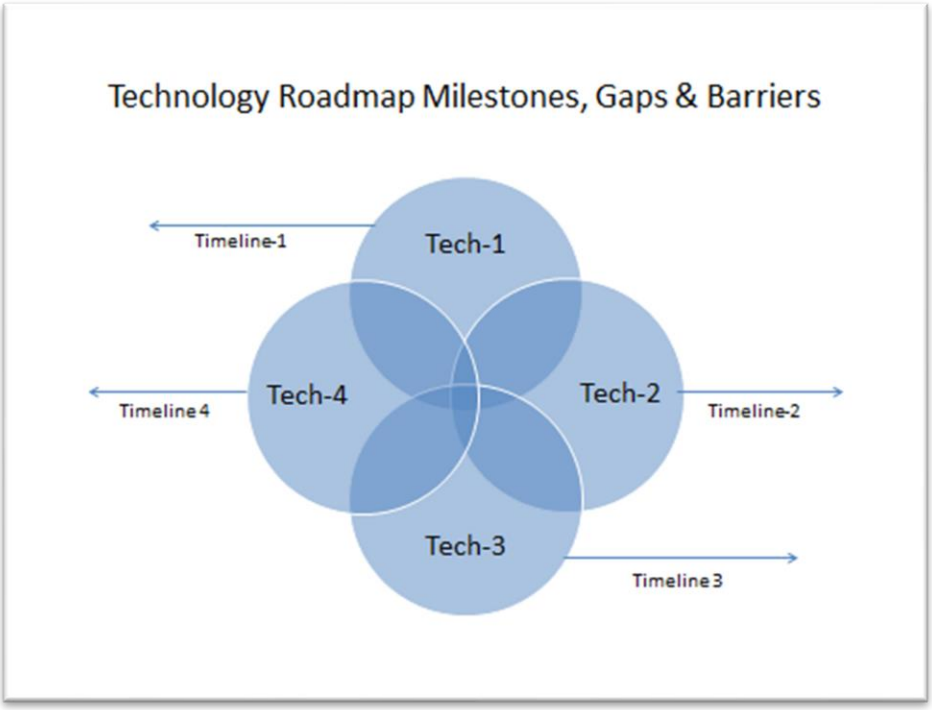
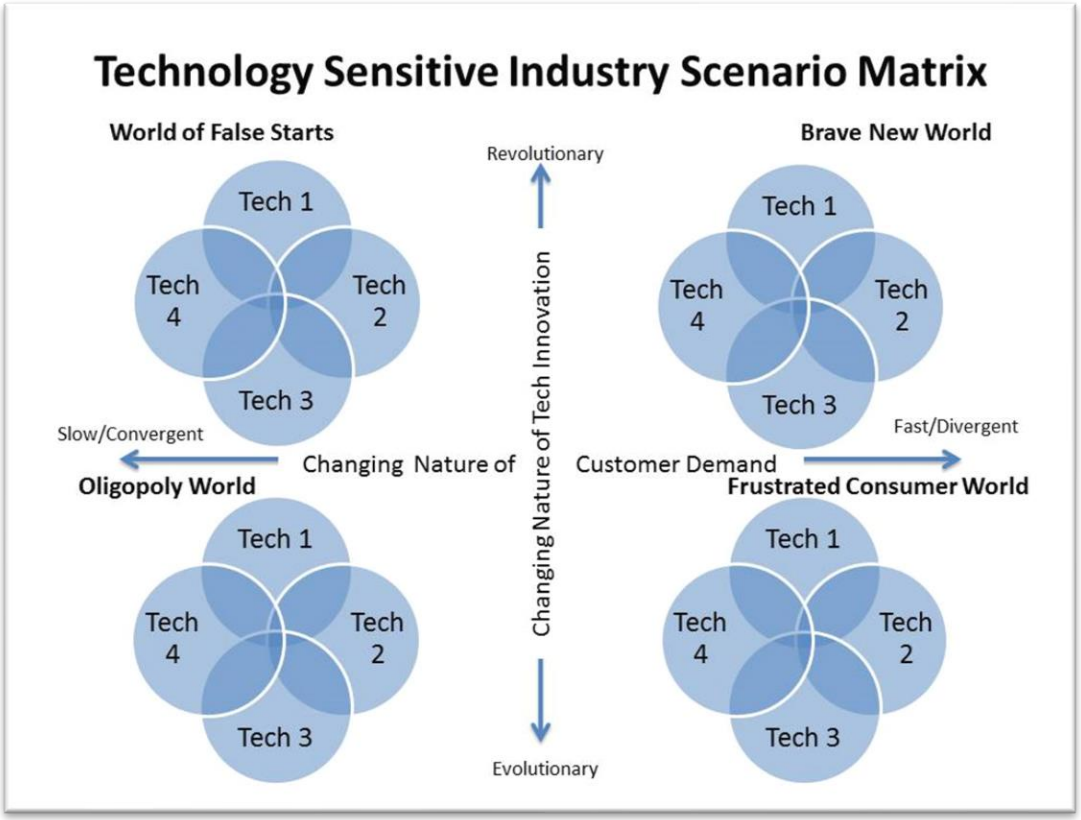


Exhibit 5 illustrates the "wind-tunneling" of the roadmap through the scenarios. This involves assuming each world emerges and assessing the underlying milestones, gaps, barriers and timelines in light of conditions in each scenario (and unfortunately another thick report). It is useful here to establish a team for each scenario. Each scenario team will "live in" the scenario and produce results for each of the latter four steps of the TR process (milestones, gaps & barriers, action items, and priorities & timelines). At key points the teams should share their working results as it will help other teams see things they might miss or can use. Engineering and R&D staffs find this level of detail gives them the specific information they need to set priorities for directing research talent and spending.

Exhibit 5



Comparing the results of each team's work and understanding the similarities and differences is where a lot of value is gained. The knowledge gained here is the essence of wind-tunneling. Viewed from the industry level, comparing and contrasting the analyses of the roadmaps across the scenarios can feed deeper consideration of uncertainty. Seeing the differences here can also reduce the risk of proceeding in wasteful directions that have lost value because of shifts in the market or business environment. An industry (or company) focused on the "Brave New World" that is prepared for "World of False Starts" or "Oligopoly World" can avoid a lot of losses. For example, Google's failure with Google-Internet-connected eyeglasses might have assumed a "Brave New World" for that technology, which would be an expensive false start. Or conversely an industry focused on "Oligopoly World" might find new opportunities if it is prepared for "Brave New World." In the late 1990s Microsoft may have seen cell phones and apps as existing in "Oligopoly World" when Steve Jobs and Apple imagined them as personal digital assistants in a "Brave New World."

At the proprietary company level comparing and contrasting the scenario roadmaps can be used to isolate valuable strategic investments and uncover risks. Existing product and service developments might be shown to be successful in one scenario, but highly problematic in another. Using these insights plans can be changed and new options developed.

Keeping track of key early indicators from the scenarios can be especially valuable at this point by signaling emerging trends that have strategic importance. Early indicators for each scenario can be created by assuming each scenario emerges and looking at the key drivers to see what emerging events

in those areas might be signaling a particular scenario. Technology development, customer demand changes, and economic shifts mentioned in the scenario may be especially good places to look for early indicators. Market-derived and public-policy-related early indicators can be as important as technologically related ones. Early indicators might also signal movement from one scenario world to another. At the industry level monitoring early indicators can signal structural changes that might influence the direction of investments. At the company level monitoring early indicators can support pro-active versus reactive strategy making (options have been thought of in advance and specific signal identified. Monitoring and holding regular strategic conversations about the meaning of early indicators can be the core of long-term continuous learning within a company. The firms that understand and properly interpret early indicators can take advantage of opportunities other may miss and gain competitive advantage through entering the market earlier with products meeting more quickly identified customer wants.

To complete the scenario analysis process in TR and bring the work together into a cohesive plan for moving forward requires a final step of gathering the robust results at the action items and priorities level of the comparative work. Robust actions and priorities are the ones that worked well across all of the scenarios. Essentially this is a step of prioritizing the comparative analysis from the scenarios by isolating those technology action items and priorities that had value in all of the scenarios. This brings the group back to a consensus for moving ahead. The process is identical within a company in finding proprietary actions that are robust.

It can also be useful to draw from the scenario-specific TR work some important contingent actions and priorities that can be connected to one or more early indicators. These contingent actions and priorities can exist at both the industry and company proprietary level and are a part of pro-active planning as decision makers can have an idea of what unfolding events might indicate for action.

In summary, technology roadmaps are valuable tools for directing technological innovation in coordination with key stakeholders and company representatives. But it's perilous to ignore the uncertainties that underlie technological innovation especially where there is commercial development.

By deeper use of the tools of scenario analysis to generate and assess a wider range of investment options, to monitor areas of uncertainty, target opportunities for learning, and recognize structural shifts, industry-wide development of new technology can proceed more productively. For companies participating in technology roadmaps for developing proprietary strategies the wise use of scenario analysis offer can offer improved strategy development and potential competitive advantages.

Endnote on Long Term Technological Evolution

Truly innovative and new technological capabilities emerge from discovery of new knowledge. Basic scientific study therefore is a first essential step. Based on Pasteur's Quadrant and the work of Donald Stokes shown below is a chart that suggests how discovery and technological innovation are related over the long term. It suggests that basic research with no particular application in mind (just knowledge) is where innovative discoveries begin (SW quadrant). With a discovery targeted applications can begin. Targeted applications lead to targeted and applied research to increase value of related products and services. On rare occasions something is discovered unintentionally while performing targeted research that has a wide range of applications.

Exhibit 6