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Strategic Marketing Planning for Radically New Products

In this article, the author outlines an approach to marketing planning for radically new products, disruptive or discontinuous innovations that change the dimensionality of the consumer decision. The planning process begins with an extensive situation analysis. The factors identified in the situation analysis are woven into the economic webs surrounding the new product. The webs are mapped into Bayesian networks that can be updated as events unfold and used to simulate the impact that changes in assumptions underlying the web have on the prospects for the new product. The author illustrates this method using a historical case regarding the introduction of videotape recorders by Sony and JVC and a contemporary case of the introduction of electric vehicles. The author provides a complete, numerical example pertaining to a software development project in the Appendix.

These are times of unprecedented technological change. Stuart Kauffman (1995) equates this technological revolution to the Cambrian explosion during which three times as many phyla[1] existed as remain today. The rapid creation (and extinction) of so many fundamentally different life forms 550 million years ago provides lessons and frameworks to help view the current tumultuous times. The strict Darwinian notion that evolution progressed by the "gradual accumulation of useful variation" would have early multicellular organisms slowly diverging. Contrary to this picture, fundamentally different phyla emerged in a brief moment of geological time—a punctuated equilibrium (Eldredge and Gould 1972; Gould and Eldredge 1993). Only after the 100-million-year extinction period did evolution proceed by variations that produced new families within the surviving phyla. Vertebrates are the only current phyla that appeared after this epoch.

So, in periods of technological revolution, gross variation in the means developed to serve common goals might be expected. Such gross variation appeared in the early evolution of bicycles (Dodge 1996) and automobiles. In the early days of automobiles, for example, Kirsch (1997) points out that steam, electricity, and internal combustion engines all sought their niches before the hybrid electrified-gasoline engine became dominant. Understanding the molar differences of the early forms and recognizing that the survivors are hybrid adaptations may make some of the new possibilities more obvious. The newest proposed hybrid (one that uses gasoline to generate hydrogen to power a fuel cell) might have been less obvious if designers thought only of pure forms or incremental evolution.

How do managers achieve perspectives on the rapidly changing times that enable them to innovate? How can people plan responsibly for such innovation? These questions underlie my efforts here. It may be that, in the face of such turbulence, the most valuable strategic assets are the mental models and tools people use to think about the future (Amit and Schoemaker 1993). I describe a framework and method for planning for radically new products. I begin by defining what I mean by "radical change." Then I describe a planning process that begins with an extensive situation analysis. The situation analysis pays particular attention to environmental change that comes from political, behavioral, economic, sociological, and technological sources. These environmental forces are studied from the points of view of the company, the business ecosystem (Moore 1996) or value network (Christensen 1997), and the infrastructure. This stage produces a critical-issues grid that helps planners stay divergent enough in their thinking that the major potential threats and opportunities are more likely to be identified. The stakeholders and factors identified in the situation analysis then are woven into the economic webs surrounding the new product by asking the question, "Who or what does each factor influence?"

The influence diagrams, or webs, are the visual schemes of Bayesian networks. A Bayesian network is a directed acyclic graph in which the arcs connecting nodes reflect the conditional probabilities of outcomes, given the range of factors and assumptions considered. To move from the visual scheme to a complete Bayesian network involves a combination of knowledge engineering (i.e., a process of translating existing expertise into conditional probabilities between nodes in the network) and specification of focused research projects to develop estimates for the unknown arcs. At first the numbers can be crude, directional approximations of the underlying processes. The Bayesian nature of the network enables planners to im-

[1]The taxonomic hierarchy goes kingdoms, phyla, classes, orders, families, genera, and species. Thus, 100 phyla then compared with the 32 surviving phyla indicates the huge variation generated during this period.

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prove the accuracy of the networks as their experience and expertise grows, to update information as events unfold, and to simulate the impact that changes in assumptions underlying the web have on the prospects for the new product.

What Is Radical About Radically New Products?

Many of the topics that are relevant for radically new products are also relevant for more traditional new product planning. Often planners do not bother to think through some issues because the company has done it before, the pattern of industry or ecosystem competition is set and will not change with the addition of a "new and improved" version of an existing product, or an infrastructure already is established that enables the smooth flow of commerce in this arena. In 1997, 25,261 new products were launched, according to Market Intelligence Service (see Fellman 1998). The vast majority of these are what the marketing literature calls continuous or dynamically continuous innovations (Engel, Blackwell, and Miniard 1986) or what the technology management literature calls sustaining innovations (Bower and Christensen 1995). These correspond to the gradual accumulation of useful variation expected by Darwinian evolution.

Radical innovations are similar to the new phyla created in long jumps across ecological landscapes. The species of the new phyla either find a viable niche in a new ecosystem or value network or die. Steam ships found a niche in river transport (where their competitive advantage over sailing ships was clear) more than 30 years before they ever made a successful challenge to sailing ships in oceanic transport. The ocean shipping companies listened to their best customers, who wanted more capacity at cheaper rates per ton than the steamers initially could provide. They put more sails on larger ships and ignored the coming "sea change." Similarly, transistors flourished in inexpensive portable radios before they were used to create the consumer electronics industry. The makers of large console radios listened to their best customers, who wanted more fidelity and greater range, and ignored the inferior goods that the early transistor radios represented to them. Christensen (1997) provides many examples of how outstanding companies that listen to their best customers and invest substantially in new technologies are blindsided by discontinuous innovations and ultimately lose their markets. These are examples of discontinuous or disruptive innovations that change the dimensionality of the consumer decision process and revolutionize product markets. To understand what I mean by this, radical change must be studied from a consumer's perspective.

The framework for classifying change comes from Golembiewski, Billingsley, and Yeager's (1976) work, in which they expand on the traditional understanding of change. Instead of assuming that change is a single, unified concept, Golembiewski, Billingsley, and Yeager distinguish three distinct types of change:

- *Alpha change* is a variation measured on a fixed scale. In this context, this kind of change amounts to repositioning a brand in an existing framework, such as a perceptual map. The dimensions do not change, nor is there any implied change in what people value. Rather, the attempt is to realign the brand image to capture existing values better. An advertising campaign to lend Oldsmobile a sportier image would be an example of an alpha change.
- *Beta change* is a variation measured on a changing scale. A beta change occurs when values change with a corresponding change in ideal points in a product map. For example, when children finally leave home, parents can indulge their desire for sportier cars. Without any change in brand positioning (i.e., alpha change), sportier cars are preferred because the consumer's values have changed.
- *Gamma change* is a variation that can be measured only by adding a new perceived dimension to product positioning that redefines the products and ideal points in a perceptual map of a market. If General Motors introduces an electric vehicle, consumers must consider recharging stations; rethink carpooling notions; and reset expectations about acceleration, trip distance, and reliability. These factors change the dimensions of the problem, which is the defining characteristic of gamma change.

Products are radically new from a consumer perspective when gamma change occurs. Even gamma changes come in widely varying degrees. A single dimension reflects the least change I consider radical from a consumer perspective. A technological revolution that reshapes where and how people work or how they live their family lives engages many new dimensions of experience and expression. Be it one- or many-dimensional, gamma change should cause planners to rethink what are often considered settled questions about the environment and infrastructure.

Understanding the Competitive Environment

An Open-Systems Model for Marketing and the Firm

A firm is analogous to a living system or an organism attempting to navigate its course through a mixed economy. As do all living organisms, a firm has a semipermeable boundary between itself and the competitive environment. Its receptivity to resources and resistance to threats are managed actively by the boundary.

The marketing function can be thought of as one that regulates the flow of resources (in both directions) across the organizational boundary. This broad mandate for marketing inherently emphasizes the importance of understanding the environments that surround an organization and, particularly, of anticipating radical change. The turbulence inherent in times of radical change affects the marketing function (i.e., boundary management). Emery and Trist (1965, p. 26) use open-systems theory to explain how an organization interacts with elements in a turbulent environment: "In these [turbulent environments], dynamic processes, which create significant variances for the component organizations, arise from the field itself. The 'ground' is in motion." In an environment with this much uncertainty, Emery and Trist believe that certain social values will emerge as coping mechanisms. To succeed in this environment, an organization must form organizational matrices or "relationships between dissimilar organizations whose fates are, basically, positively correlated" (Emery and Trist 1965, p. 29). An organization must also strive for institutional success by working toward goals that fit its character and moving in a direction that converges with the interests of other organizations (e.g., suppliers or alliance partners) in the matrix. Radical change and turbulent fields go together. The direction of causality may not be clear, but some of the organizational consequences are. The emphasis in the following discussion on issues of forming interorganizational alliances, setting standards for an industry, and/or issues of product compatibility largely arises from Emery and Trist's implications for organizations whose fates are, basically, positively correlated. I observe this in the networked interorganizational structure binding high-technology firms. In the "old days," the high-tech industry was structured vertically: a single company provided hardware, peripherals, operating systems, applications, marketing, sales, training, and service. IBM did this for mainframes, and DEC did it in the minicomputer market. In the current era of explosive technological progress, there are networks of companies, each producing the component that it produces best but having its fate codependent on other firms in the web. Intel creates central processing units and motherboards; Rambus designs memory chips; Microsoft creates operating systems and software applications; Trilogy provides systems integration; Dell provides final assembly, marketing, and distribution; UPS and FedEx ship; and other firms provide service and training. This is what is meant by organizations whose fates are positively correlated. This also occurs when Procter & Gamble sits down with Unilever, Clorox, Nestlé, and Johnson & Johnson to set standards for Internet advertising (Beatty 1998).

Although Emery and Trist's (1965) notions of turbulent fields were based on general systems theory (von Bertalanffy and Rapoport 1956), cybernetics (Ashby 1956), and some organization theory of the time (Schön 1971), the same conclusions can be reached by several other theoretical paths. Transaction cost economics (Coase 1937, p. 386) asserts that a firm will tend to expand to the point at which "the costs of organizing an extra transaction within the firm becomes equal to the costs of carrying out the same transaction by means of an exchange on the open market." Therefore, the vertical dinosaurs ruled the computer landscape when the expertise was narrowly held. To get things done, IBM had to invent the hardware and software and create a manufacturing process, as well as processes for distribution, installation, and servicing. The search costs to find buyers and sellers were huge, as were information, bargaining, decision, and enforcement costs (see Robertson and Gatignon 1998; Shapiro and Varian 1999). Optimal firm size was understandably large. But to maintain its dinosaur status when expertise was more widely available, IBM had to be nearly the best of breed in all the separate functions. The downsizing and outsourcing trend of the 1980s accelerated a perhaps inevitable process by ensuring a ready supply of experts and innovators to compete for each element in the value chain. As the transaction costs drop, the optimal firm size drops. In the digital economy, transaction costs are dropping toward zero, with startling implications for optimal firm size. It should not be surprising then that providing a whole product in high-tech arenas requires a network of original equipment manufacturers (OEMs), operating system vendors, independent hardware vendors, independent software vendors, systems integrators, distributors, trainers, and service organizations—smaller organizations whose fates are basically correlated.

A similar conclusion about the evolution of industry or ecosystem structure can be reached by considering the theory of competitive rationality (Dickson 1992), resource-advantage theory (Hunt and Morgan 1995, 1996, 1997), or the extensive work in the strategic management literature on the evolution of networks and alliances (see Gulati 1998; Madhavan, Koka, and Prescott 1998; Mitchell and Singh 1996; Ramírez 1999; Ruef 1997; Schendel 1998). Zajac (1998) notes that "networks and alliances" was the single most popular topic among the 300-plus papers submitted to the Academy of Management's Business Policy and Strategy Division in 1997. Kauffman (1988, 1995) presents an analogous theory that reflects the increasing complexity of economic systems over time. His basic image is a web of added-value transformations of products and services among economic agents, akin to a biological analog of Porter's (1985) added-value chain. Technological evolution generates new products that must mesh coherently to fulfill jointly a set of needed tasks. The networked actions afford opportunities for agents to earn a living and thus maintain demand for those very goods and services. Key questions are, (1) What is the web in any given economy? (2) What technological and economic forces govern the transformation of webs over time? and (3) Do evolutionarily stable strategies (i.e., competitive equilibria) emerge, or must companies run harder and harder just to stay in place?[2] The emphasis in the theory is on the coevolution of the business ecosystem (Moore 1996). The shift is highly appropriate because of the network, or web, of efforts that is needed to deliver a whole product or for typically competitive firms to confront uncertainty together (as in the case, cited previously, of consumer firms setting standards for Internet advertising). The firms must evolve together if consumers' and firms' needs are to be met.

I begin the process of building the economic web, or business ecosystem, surrounding a radically new product by focusing on the second question and articulating the broader environment in which the radically new product must operate.

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[2]This game-theory paradigm takes its name from Lewis Carroll's Red Queen, who makes her cards run harder and harder just to stay in the same place. James Moore (1996) cites Intel as a prime example of an organization that has succeeded at playing the Red Queen Game. Geoffrey Moore (1995) credits this success as the driving mechanism behind much of the dynamics of the whole high-technology business ecosystem. The phrase that captures this competitive strategy is, "You must eat your own children or your competitor certainly will." This theme is analogous to dynamic disequilibrium theories (Dickson 1992, 1994; Hunt and Morgan 1995).

Environmental Forces

When thinking about the different environments in which a company operates, five basic environmental forces deserve attention: political, behavioral, economic, social, and technological. Each of these forces affects different aspects of the product development process. Political forces appear in form of government regulations and actions, legal precedents, or international agreements, to name a few. For example, a political issue that would affect the development of high-definition television (HDTV) is the decision by the U.S. government whether to auction off the HDTV spectrum or simply give spectra to existing broadcasters. Behavioral forces come from the consumer: how consumers traditionally interact with products and how these interactions might change with the introduction of something radically new. These issues are common in areas such as electronic banking, in which firms must overcome consumer distrust to succeed.

Economic forces stem from the consumer and the structure of markets. Any product that alters the ways in which consumers purchase goods and services inevitably will encounter economic forces. Internet airline ticket auctions provide a good example of how a new method of commerce can affect traditional guidelines of what makes a good deal. Economic forces are also in play in the negotiations over alliances, as well as issues of the scale and scope of operations.

Products that affect the way people interact with one another often encounter social forces. E-mail is a prominent example, as entirely new rules of etiquette and conduct have been invented to deal with the societal changes this product has caused.

Of these five, technological forces receive the most publicity in the media. Every day, people can read about how computers with faster processors, bigger hard drives, and more memory are enabling people to do more faster. This type of rapid progress dramatically changes consumers' expectations of what new products can do and how much consumers are willing to pay for them.

Critical-Issues Grid

The critical-issues grid provides a tool for identifying the key issues that may affect the product planning process. The grid places the five environmental forces in rows in the matrix and three points of view (company, business ecosystem, and infrastructure) as column heads. The company is part of the business ecosystem, and the ecosystem is part of the larger infrastructure. Thus, these points of view are comparable to the ground-floor view, the 1000-foot view, and the 10,000-foot view. But similar to the depth of field of different camera lenses (telephoto, portrait, and wide-angle), these different points of view bring different issues into focus. As stated in the introduction, the goal of the critical-issues grid is to keep strategic marketing planners thinking divergently enough that fundamental issues are elicited. Similar aims might be achieved by the traditional strength, weakness, opportunity, and threat analysis, by means of techniques such as STRATMESH (Dickson 1994) or discovery-driven planning (McGrath and MacMillan 1995).

The next section provides an illustration of the use of the critical-issues grid and Bayesian belief networks to illustrate the economic web in a real but historic case. The case is based on a historical analysis of the planning undertaken by Sony Corporation for the U.S. introduction of BetaMax videotape recorders (VTRs).

Planning for Sony's BetaMax

"'We don't believe in market research for a new product unknown to the public ... so we never do any. We are the experts'" (Lyons 1976, p. 110). Although there are good reasons to believe that traditional marketing research is less valuable for radically new products than for sustaining innovations (Christensen 1997), to a business executive of the 1990s these words sound like corporate suicide. But these are the words of Akio Morita, the legendary cofounder of Tokyo Communications, who was responsible for many successful product launches for the firm that later became the Sony Corporation. This philosophy provides insight into the history of Sony's introduction of the BetaMax VTR.

Because Morita did not believe in scientific market research, he positioned Sony's products by deciding what the best uses would be and then selling those reasons to consumers. This approach worked well in Japan for the BetaMax but was much less successful for the BetaMax introduction in the United States. Morita regarded the primary function of the product as freeing people from a preset television programming schedule. By using the BetaMax, consumers could "time shift," or watch their favorite programs at whatever time was the most convenient rather than only when the network decided to air the show. Sony also planned eventually to introduce a video camera for consumers to record home movies when VTRs formed a large enough installed base, but Morita regarded this use as secondary to time shifting. The company's biggest concern about the BetaMax introduction was whether consumers would be willing to spend the $1,400 then necessary to purchase a VTR. Table 1 shows how the issues considered by Sony would fit into the critical-issues grid.

The blank cells in the critical-issues grid illustrate how the planners at Sony overlooked social issues and how they might affect the diffusion of the BetaMax. On closer inspection, these are crucial omissions. One of the biggest social changes brought about by the VTR was the ability of people to stay at home and watch movies together rather than to go out to a theater, which was favored by the demographic shifts as the baby boomers began having babies of their own. Sony did not consider the possible consumer demand for full-length feature films on videocassette, though its "Video Flight" equipment had been used for this purpose since the early 1960s. Instead, Sony believed that the major demand for prerecorded cassettes was in the area of historical events (e.g., Time-Life programs). When Sony chose to make its product incompatible and its tape length 60 minutes and decided not to enter into OEM agreements, it did so without considering the potentially enormous impact of movie rentals and sales. In another major oversight, Sony did not plan how to deal with copyright issues until Universal Pictures brought a lawsuit against the firm. Sony could

TABLE 1
Sony's Critical-Issues Grid for Videotape Recorders

	Focus		
Environments	**Company**	**Business Ecosystem**	**Infrastructure**
Political			
Behavioral	Time shift		
Economic	Can product be priced low enough?	OEM and licensing agreements	Manufacturing capacity
Social			
Technological	Picture quality and recording time	Compatibility with other VTRs	

have saved much time and money by anticipating this conflict of interests and attempting to work out an agreement with Universal and others before the issue led to lawsuits. Table 2 shows how the grid could have been filled in to increase the likelihood that Sony considered these (and other) issues.

Copyright issues dominated the political landscape. The company faced lawsuits, as did others in the industry. The ability to influence copyright legislation in the United States is an important consideration. The behavioral environment had unanswered questions about learning to use home electronics and what broadcasters could do to make taping easier (i.e., standards). The economic environment brought forward issues regarding OEM licensing agreements and their effects on overall manufacturing capacity. The biggest unexplored territory was the social environment. Would the movement toward nesting encourage industries whose inventory cost structure encouraged a "one-format" standard (such as movie rentals) in a way that home movies and time shifting did not? And the technological environment raised issues pertaining not only to picture quality for the company but also to compatibility among products within the nascent industry and to plug compatibility of all the products with television sets.

When these issues are included in the grid, it is possible to move to the next step of the planning process, which is to determine how they fit together and affect one another. Sometimes storytelling, as in scenario planning, helps articulate what affects what (see Schoemaker 1995; Schwartz 1996). The web for Sony distills 13 critical issues or factors from the grid that affect Sony's ability to meet consumer needs: tape length, ease of manufacturing, production capacity, licensing agreements, OEM agreements, strategic alliances, price, quality, copyrights, demographics, time shift

TABLE 2
Improved Critical-Issues Grid for Videotape Recorders

	Focus		
Environments	**Company**	**Business Ecosystem**	**Infrastructure**
Political	Copyright infringement	Lawsuits brought by Universal, Disney, and so forth	Legislative copyright decisions
Behavioral	Time shift	Can people buy tapes from other companies?	Do the networks have to change anything to make taping programs possible?
Economic	Can product be priced low enough?	OEM and licensing agreements	Manufacturing capacity
Social	Will people watch movies in theaters or at home with the videocassette recorder?	Can people rent movies?	Do demographic shifts favor one use versus another (cocooning)?
Technological	Picture quality and recording time	Compatibility among manufacturers	Plug compatibility with televisions

demand, home movie demand, and video rental/sales demand. Regarding tape length, Sony initially was committed to a one-hour tape length. Although this adversely affected video rental/sales demand, it was fine for making home movies. One hour was generally enough to tape regular television shows but not specials. The technology required to make longer tapes also made manufacturing more difficult, so Sony had a manufacturing advantage with a shorter tape length but a disadvantage regarding fulfilling the customers' needs. Sony introduced its two-hour format in March 1977, six months after JVC came to market with a two-hour recording time (see Cusumano, Mylonadis, and Rosenbloom 1992). Regarding ease of manufacturing, note that the manufacturing process directly affects production capacity and price. If manufacturing is difficult, production capacity should be lower and price higher. If it is easy, larger production capacity and a less intensive process should lead to a lower price.

As shown in Figure 1, these factors weave together into an economic web. Instead of dealing with the critical factors either separately or as if these factors all interconnect, building an economic web simply asks the strategic planning team to determine what influences what. In this example, OEM and licensing agreements affect the likelihood of forming strategic alliances. Alliances affect ease of manufacturing and production capacity, as well as possibly influencing the quality of the final product. Product quality and tape length affect the difficulty of manufacturing. Alliances, production capacity, and ease of manufacturing affect price. Price, product quality, tape length, and production capacity affect the extent to which consumers' needs are met. The extent to which consumers' needs are met also is determined by the need for home movies, video rentals, and time shifting. Although demographic shifts affect all three of these needs, copyright issues only affect video rental/sales and time shifting. An analogous set of factors influences JVC's ability to meet consumer needs (not pictured). The extent to which all the market's needs can be met by one format affects the likelihood that one format will endure.

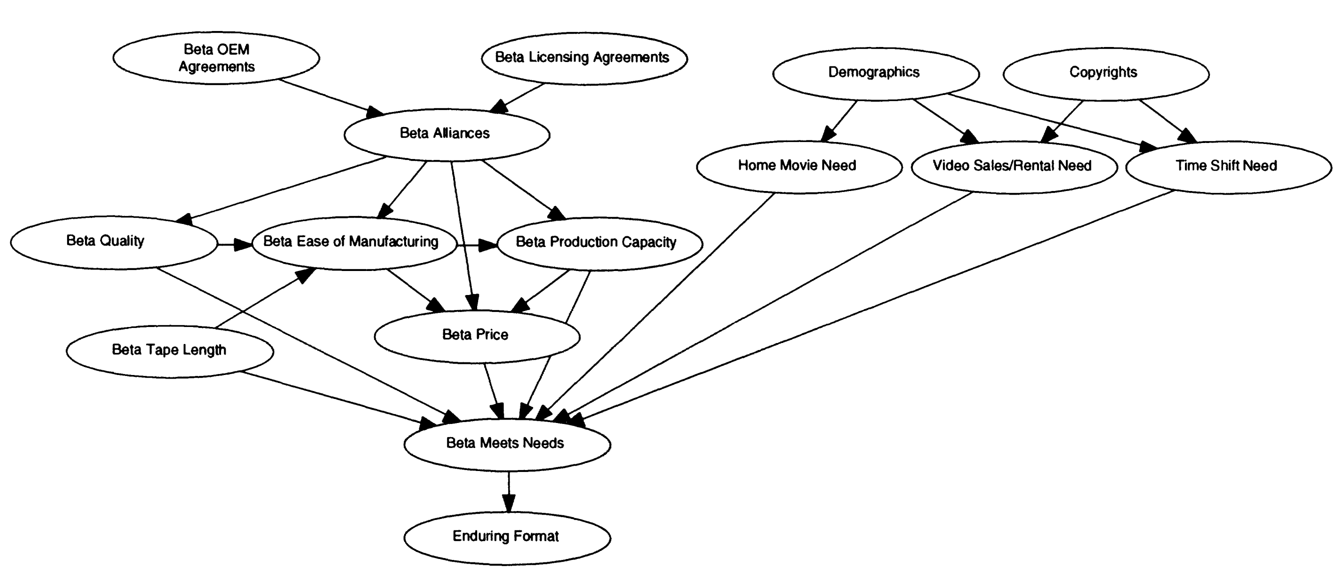
I do not wish to overstate the diagnosticity of a historical example. Demonstrating the same potential for 20–20 hindsight, however, Arthur (1988) comes to a different conclusion. He uses the Beta versus VHS format as an illustration of path dependence (i.e., how early random events can lead a random walk process to lock in a particular standard). Although his general framework provides a powerful conceptual model that drives much of the thinking about economic webs, I believe the critical-issues grid provides a framework that takes some of the randomness out of the process or at least widens the scope of potential conclusions.

Bayesian Networks

Bayesian networks were developed (Pearl 1986) in an attempt to devise a computational model of human reasoning, or of how people integrate information from multiple sources to create coherent stories or interpretations. Although Bayesian networks are inherently more accurate than people, their mandate closely parallels the roles such networks are designed to play in this planning method. From the multiplicity of issues highlighted in the critical-issues grid, the planning group is charged with creating scenarios that represent plausible futures.

The human reasoning process (and the associated storytelling process) is represented as a process that links judgments on a small number of propositions (e.g., statements or assertions) at a time, such as the likelihood that companies will be allowed to export strong encryption technology, given the current composition of Congress and the White House, or what happens to encryption export policy if the composition of Congress changes. Quantitative mapping of stories told with such elements relies on rather simple judgments. Are two propositions, x_i and x_j, dependent or independent? Does x_i influence x_j directly, or is the in-

FIGURE 1
Bayesian Network for Sony's BetaMax.



fluence indirect, through a third proposition x_k? Pearl (1986) asserts that people tend to judge such two- or three-place relationships of conditional dependency with "clarity, conviction and consistency." This avoids the inaccuracies in syllogistic reasoning that are well documented in the social cognition literature (Wyer and Carlston 1979). Simple conditional judgments also avoid the "conjunction fallacy" (Tversky and Kahneman 1983), in which people judge the joint occurrence of two events as more likely than that of either one alone (a clear violation of the laws of probability). The scenario is sketched into a graph in which the nodes represent certain propositions and the arcs link propositions that the scenario says are directly related. The functionality of the mapping requires consistency and completeness, linguistically and probabilistically. Linguistically, this amounts to telling stories that have a beginning, middle, and end. The probabilistic requirements are discussed next.

These types of maps are called *directed acyclic graphs* (dags). Such maps use concepts of conditional independence and graph separability to make it easier to compute the implication that a change in one state or conditional probability has for all other nodes in the graph. Two propositions, x_i and x_j, are conditionally independent, given some subset S, if S separates x_i from x_j (all paths between x_i and x_j are blocked by S). In the Sony example in Figure 1, prices are conditionally independent of licensing because all the influence of licensing on prices is reflected in the alliances node (i.e., alliances separate licensing from prices).

The utility of this framework stems from the simplicity of the computational building blocks. The basic equation for conditional probabilities says that the probability of event x_i occurring, given that event x_j has occurred ($p[x_i|x_j]$), is the ratio of the (joint) probability that both events occur ($p[x_i\ x_j]$) to the (marginal) probability that event x_j occurs ($p[x_j]$):

(1) $$p[x_i|x_j] = p[x_i\ x_j]/p[x_j].$$

Simple algebra shows that the joint probability ($p[x_i\ x_j]$) is the product of the conditional probability ($p[x_i|x_j]$) and the marginal probability ($p[x_j]$). The principle is easily extended (by the chain rule for joint distributions) to represent a complex joint probability of a series of events ($x_1, x_2, \ldots, x_n$) as the product of conditional probabilities and marginal probabilities:

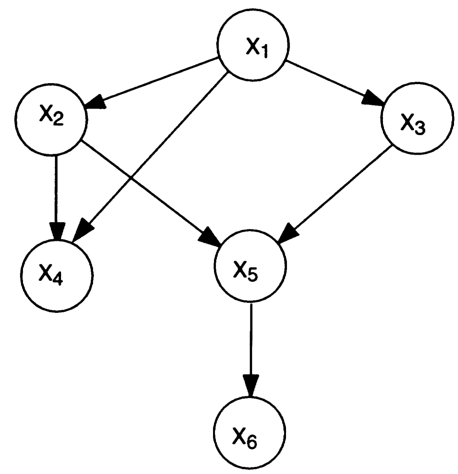
(2) $$p(x_1, x_2, \ldots, x_n) = p(x_n|x_{n-1}\ x_{n-2} \ldots x_1)\ p(x_{n-1}|x_{n-2}\ x_{n-3} \ldots x_1) \ldots p(x_2|x_1)p(x_1).$$

With only one term on the left of the conditioning bar of each component, this formula helps ensure that a complete and consistent quantification of the events (nodes) and relations (arc) of any arbitrary scenario map can be found.

Separability helps simplify computations by asserting that if S_i is the complete set of parent nodes that have *direct* links to an event x_j, only the conditional probabilities $p[x_j|S_i]$ must be assessed rather than all the expressions on the right side of the conditioning bars in Equation 2. Pearl (1986) provides an example of a simple map involving six nodes, as is depicted in Figure 2.

Separability means the joint probability, $p(x_1\ x_2\ x_3\ x_4\ x_5\ x_6)$, is found from

FIGURE 2
Hypothetical Bayesian Network



(3) $$p(x_1\ x_2\ x_3\ x_4\ x_5\ x_6) = p(x_6|x_5)p(x_5|x_2\ x_3)\ p(x_4|x_1\ x_2)p(x_3|x_1)p(x_2|x_1)p(x_1).$$

Thus, instead of needing to assess the awkward joint probability that a series of states probabilistically assumes (and possibly encountering the *conjunction fallacy*), only simpler conditional and marginal probabilities are required. If the experts in the planning process understand the relation, elicitation is a matter of knowledge engineering. If unknown, there is implicitly a rather well-specified research question to address. Crude directional indications can be entered and the precision can be improved as research results are found.

Implementing the Bayesian Network

For the historical case, to determine conditional probabilities for each node, I looked back to determine the external environment at the time of the BetaMax launch and Sony's internal corporate thinking. For example, in determining the probability that Sony would license its products or enter into OEM agreements, I assigned fairly low probabilities on the basis of documentation of Sony's reluctance in these areas. In determining the probabilities for environmental factors, such as various demographic scenarios or legal copyright decisions, I based my assumptions on the historical realities of the time. A demographic example is the high probability that baby boomers would want more in-home entertainment as they settled down and had children.

When the probability of each parent node was determined, I determined conditional probabilities for each offspring node depending on the outcome of the parent node. For nodes that are dependent on the outcomes of many other nodes, it is necessary to determine probabilities for many possible outcome states. In the case of home movie demand, probabilities for high versus low demand depend on price (two possible outcomes), demographics (three possible outcomes), and tape length (two possible outcomes). This creates 12 different conditional probabilities depending on the exact scenario that occurs.[3] As the number of influences on any given node increases, the number of conditional probabilities that must be evaluated grows multiplicatively. But as in the two examples that follow, by simply focusing on the major links, manageable networks result. Using general conceptual frameworks such as the three Cs (company, customers, and competitors); Porter's (1980) five forces; Dickson's (1994) five environments mental model, or STRATMESH; or the political, behavioral, economic, social, and technological environments can help structure the network into separable chunks that ease the task of eliciting conditional probabilities.

By inputting all this information into a Bayesian network, it is possible to track the events that lead to different market outcomes. The two most interesting scenarios to track are that which leads to the 50–50 split expected from the random walk that Arthur (1988) assumes and that which foresees high nesting and high demand. The random split scenario derives from assuming a high emphasis on product quality and no nesting by the baby boomers' relatively low demand for home movies, time shifting, and video sales/rentals. In these conditions (and the other default values), the Bayesian network indicates that VHS and Beta each have a 20% chance of becoming the enduring format. There is a 54% chance they both will endure and a 5% chance that neither will. Contrast this with the scenario that assumes high nesting and high demand. With these two assumptions (and the default values used in the random walk scenario), the same network gives VHS an 88% chance of becoming the enduring format and Beta less than a 2% chance. The detailed probabilities are available from the Project Action Web site (http://164.67.164.88). The details for a smaller numerical example pertaining to software development appear in the Appendix.

Five things are gained from this undertaking: (1) a process that makes explicit the often implicit assumptions that underlie the planning process and broadens the scope of the assumptions considered, (2) a visual overview backed by a complete quantitative statement of the likelihood of events, (3) guides to where research projects are needed to fill in the uncertainties in the planning process, (4) a method for combining subjective (engineered) expertise with more objective research results, and (5) a Bayesian network that allows for better understanding of how changes in scenario assumptions affect the likelihood of important planning events.

As time unfolds, events that underlie network issues should occur. Pending legislation on copyright is enacted. Industry standards are adopted. Speculation becomes certainty. The Bayesian nature of the network allows for easy updates of the conditional probabilities and revelation of the implications for decision making. If someone writes a traditional planning document, it is outdated before it is read. A planning document developed from this approach is as dynamic as the turbulent times in which people live and work today. A traditional planning document is dead when the project moves into implementation. With this approach, implementation can be woven into the strategic planning document.

I have used this approach to strategic marketing planning in ten contemporary projects with teams of MBA students and am undertaking a second industry project (under a nondisclosure agreement). The MBA teams studied the potential market for electronic shopping agents and the issues surrounding the introduction of Olean™, enhanced television, DVD™ versus Divx™, smart cards (Swatch Access II Network™), Internet-based payment services, satellite-to-personal computer connectivity (Adaptec's Satellite Express™), video on demand, personal computers on a chip (National Semiconductor), and electric vehicles.

In each of these projects, the economic web fell directly out of an understanding of the stakeholders and the environmental issues that bind them together. In the case of electric vehicles, the stakeholders cluster into consumer and ecological groups, those representing interests in petroleum and electricity, political stakeholders, and car manufacturers, as is shown in Table 3. Even a high-level, critical-issues grid has multiple issues in each cell, as is shown in Table 4.

The stakeholders and issues form an 89-node Basyesian network whose aggregate structure appears in Figure 3. The network represents the decision by an existing car manufacturer to introduce an electric vehicle product. More specifically, the root node labeled "supply" asks whether the electric vehicle manufacturer will be able to produce adequate supply given four main factors: consumer demand, manufacturing investment, government requirements, and government assistance. Consumer demand is influenced by clusters of issues pertaining to education and information (public education, company marketing and promotions, and *Consumer Reports* support), the value proposition (safety, performance, aesthetics, and total cost of ownership), and social acceptance (age range acceptance, driving pattern changes, human interaction changes, and trendiness of electric vehicles). Manufacturer's investment is affected by manufacturer economics (fixed and variable costs), partnerships/alliances, and success of competitors (hydrogen fuel cells, flywheels, and internal combustion engines). Government requirements are affected by lobbying (constituents, environmental lobbying, and corporate lobbying), global regulations (emissions credits and global economics), and domestic regulation (regional and national laws). Antitrust laws, patents, and the likelihood of subsidies affect government assistance. Many of these nodes have more detailed nodes that account for the factors that underlie them. Instead of a simple list of assumptions, the Bayesian network shows the planning team's idea of how the assumptions interrelate. If the major flywheel designers quit the competition, that node could be changed to reflect the narrower competition. The planning document does not need to be discarded as out of date, and planners are not left wondering what such an event means. The

[3]Although Bayesian networks allow for continuous relationships between events or issues, I simplified this example to have only discrete states. Discrete states were used in the dozen examples to date and are likely to be more appropriate in the early applications of this planning framework. The Hugin Web site (http://www.Hugin.dk) has tutorials to help users work through the numerics and free software for developing networks of less than 200 nodes. The largest network undertaken so far was substantially smaller than this limit.

TABLE 3
Stakeholders in Electric Vehicles

Stakeholder Groups	Parties	Interests
Consumers	Individual, rental, corporate fleet, public transportation	•Performance •Total cost of ownership •Convenience
Ecological	Environmental Protection Agency, Sierra Club, World Population	•Environmental protection
Petroleum	Petroleum companies, foreign governments of petroleum exporting countries	•Maintain demand for petroleum
Electric	Battery manufacturers, public utilities	•New sources of revenue •Technological gains •Efficient use of available capacity
Political	Local, national, and foreign governments	•Decrease or maintain demand for petroleum (depending on perspective) •Serve constituents
Car manufacturers	World manufacturers, new ventures	•Profitable production •Servicing consumer demand

Bayesian network provides a clear portrayal of how such an event affects the overall scheme. This largely hierarchical structure helps organize thoughts and introduces the separability that simplifies the elicitation of conditional probabilities.

One clear limitation of the Bayesian network is its inability to reflect feedback loops. These are dags and cannot feed back on themselves. Positive feedback in markets occurs when, for example, an increase in an installed base leads to an increase in the value of a software product to that base, which leads in turn to a further increase in the installed base. The problem is that Bayesian networks deal only with the first-order effect—an increase in an installed base leads to an increase in the value of a software product to that base. In a positive feedback situation, there is a second-order effect and the potential for a nonlinear evolution of the system. Representing such nonlinear evolution in Bayesian networks is a difficult and serious problem. The solution may be to construct a second-order Bayesian network model that predicts the next cycle of interaction between changing demand and changing supply. This potential approach requires much more thought and study.

Another limitation deals with the compounding of errors that can occur when multiplying probability estimates. Consider, for example, if there are just four probabilities whose true values are .5. Overestimating them each by 10% leads to a product that is overestimated by more than 46%. One way to cope with this inherent limitation is to perform computational sensitivity analysis experiments on the networks (Bankes 1993, 1994; Lempert, Schlesinger, and Bankes 1996) to find the policy variables that most influence final outcomes and then to invest the resources needed to increase the accuracy (or at least unbiasedness) of the probabilities that are most influential.[4]

Courtney, Kirkland, and Viguerie (1997) discuss the pitfalls of setting strategy in the face of uncertainty. They provide a useful framework of four levels of uncertainty. Level 1 is "a clear-enough future" (p. 69). They claim that standard practice at least implicitly assumes Level 1 uncertainty. If Level 1 is a reasonable assumption, this Bayesian approach to planning will work extremely well (as will many other approaches). At Level 2, "the future can be described as one of a few alternate outcomes or *discrete scenarios*" (p. 69). Here, though outcomes are not certain, probabilities for whole scenarios may exist. The Bayesian approach will work here, as will scenario planning. At Level 3 a "range of futures" exists. The "range is defined by a limited number of key variables, but ... [t]here are no natural discrete scenarios" (p. 70). With this level of uncertainty, scenario analysis begins to wane in value. Scenario generation (Schoemaker 1995; Schwartz 1996) builds general stories of possible futures. When the future unfolds in a way that does not correspond to the exact scenario assumptions, the scenario planners are left to either start over or guess at the underlying network. The Bayesian approach, however, combined with policy simulations (Bankes 1993, 1994; Lempert, Schlesinger, and Bankes 1996) still can provide valuable quantitative insights to the strategic questions. At Level 4 ("true ambiguity"), "multiple dimensions of uncertainty interact to create an environment that is virtually impossible to predict" (Courtney, Kirkland, and Viguerie 1997, pp. 70–71). Strategic decisions still must be made. A lot of strategic marketing planning begins as a vague, subjective process. The methods discussed here also can start with subjective generalities, cataloging what little is known or knowable at that point in time. When, in the early stages of strategic marketing planning, the relations are simplified and vague, the output is limited in accuracy. The resulting probabilities should be read as directional indicators of the impact of the underlying influences or critical factors. However, this approach provides a coherent underlying mechanism for becoming more precise as more is learned.

[4]For more information on computation modeling for policy analysis, see http://www.EvolvingLogic.com.

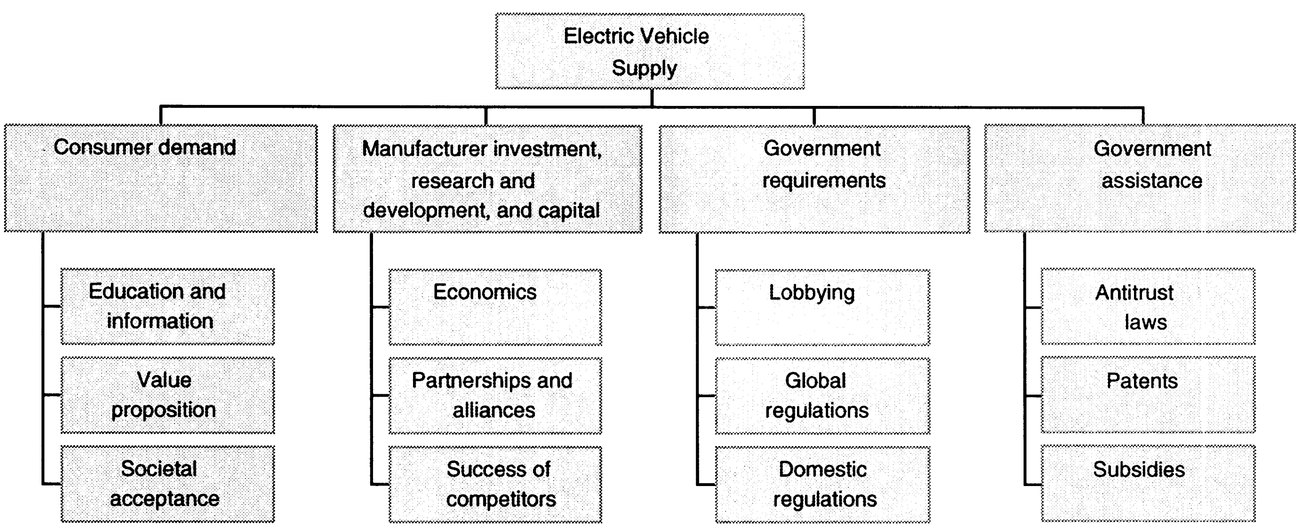
TABLE 4
Critical-Issues Grid for Electric Vehicles

	Company	Industry (Business Ecosystem/Value Networks)	Infrastructure
Political	•Department of Energy hybrid electric vehicles Propulsion Program •Antitrust •Tax incentives •Law requirement •Battery patents	•Federal Clean Air Act •New York 2% law •Utility deregulation driving 20% cost decrease in electricity •Energy Policy Act of 1992 •Clean Cities partnership •Executive Order 12844 stepping up federal fleet alternative-fuel vehicle purchases •Regulatory pressures	•Hybrid electric vehicles Propulsion Program •Federal Tier II Emissions Standards •Federal motor vehicle safety standards •Emergency response preparedness (education of groups about electric vehicle dangers) •Subsidies for refueling stations, regulatory bodies set rates for electric companies •Policies to stimulate the development and deployment of electric vehicle infrastructure support systems
Behavioral	•Will people use electric vehicles for commuting only and have a second car for longer trips? •Can cars be produced that are as safe as traditional vehicles (battery and flywheel are major elements of safety)? •Will cars perform (speed and acceleration) at a level of satisfaction to consumer? •Availability of vehicle purchasing sites and acceptability of vehicle cost/performance (refueling and maintenance) •Car design and distance of commute •What will be the daily refueling process? How will that affect lifestyles?	•Are other means of transportation as low cost and convenient? •Will industry research convince consumers of safety/reliability of electric vehicles?	•What role will stakeholders have in promoting product acceptance? •What public education will be developed to promote acceptance of products? •What will be the added value of charging stations (automatic billing, load management, vehicle security)? •How will tow trucks deal with dead battery situations? •Will refueling facilities be conveniently located—at home, office or other central point? •Will carpool lane rules be adapted to include more lenient allowance for electric vehicle commuters? Will carpooling decrease if size of cars is smaller due to lower performance motors? •Will electric vehicles change driving patterns (e.g., refueling time requirements, battery driving range)?
Economic	•At what demand will technology costs be low enough to allow greater production and reasonable pricing to consumers (break-even costs)? •Will companies offer leasing options in addition to sales (e.g., Toyota already is offering a purchase price of $42,000 or a three-year lease price of $457 per month)? •Existing purchase commitments by local governments and private fleet operators will encourage electric vehicle manufacturers to make products available	•What demand will be required to provide incentive for car companies to produce the electric vehicles (minimum efficient scale)? •What type of manufacturing and distribution network will exist for parts and maintenance? •Will import tariffs favor domestic sales of electric vehicles and promote higher prices? •Will utility companies offer affordable recharging (e.g., discount for off-peak hours)?	•Will incentives exist for third parties to build refueling stations? •Will recycling offer cost advantages?

TABLE 4
Continued

	Company	Industry (Business Ecosystem/Value Networks)	Infrastructure
Social	•Will people widely accept usage of electric vehicles (socially acceptable or preferred)? •Will people use electric vehicles for the same purpose as previously using other vehicles (e.g., shopping, traveling, commuting)?	•Will electric vehicle users have fewer interactions because of less carpooling (assuming smaller cars)? •Will environmental factors speed up acceptance of electric vehicles?	•Will people have greater interaction due to need to refuel at a central location? •Do demographics or living trends favor the use of electric vehicles (e.g., short commutes, concentration near cities, single-person households)? •Can people refuel at other people's houses and reroute electricity charges to themselves?
Technological	•Will adequate technology be available to provide safety (e.g., crashworthiness, containment, material structure)? •Can batteries be developed to improve available range of electric vehicles (overall vehicle efficiency, hybrid-electric vehicle technology)? •Will larger cars be made with electric motors? •Should the engine be entirely electric or a hybrid?	•Advancements in battery technology that will increase energy storage capacity are expected through the research and development efforts of the Advanced Lead-Acid Battery Consortium and the United States Advanced Battery Consortium. •Will standardization of parts and supplies occur? •Will partnerships exist between refuelers and manufactures? •How quickly will battery technology be improved (Nickel Metal Hydride, Lithium Ion)?	•Compatibility of refueling stations (standards are evolving per agreement among major OEMs) •Will adequate battery recycling facilities exist? •Will adequate electricity supply, service, and maintenance exist? •What technological parameters (voltage/amps) are necessary at recharging stations/homes? •Can utility companies support large electric vehicle population recharging needs?

FIGURE 3
Basic Structure of the Bayesian Network for Electric Vehicles



This approach provides what is needed: a place to start, a direction for improvement, and a way to update continually a dynamic planning document. These are the basic components needed to make strategic marketing planning a vital process that is able to confront the complexities of these turbulent times.

Appendix

The ACME Software Example

This Appendix works through a preliminary example of the Bayesian networks discussed in the article. The basic situation pertains to a fictional company, ACME Software.

Approximately six months before the scheduled release of a highly touted new software application, ACME Software is concerned about allocating sufficient resources to ensure that Release 1.0 is bug-free. The head of software development can review nightly builds, but as functionality is maturing toward the final product, new opportunities for bugs are created. If major bugs are reported, the head of development can assign additional teams to the bug-eradication effort.

An influence diagram is the visual map of the factors isolated in a critical-issues grid. For this example, the situation is depicted in Figure A1. Three kinds of nodes appear in this diagram: chance nodes, action/decision nodes, and utility nodes. The chance nodes summarize the variables or factors whose influences I am trying to track. Decision nodes capture the decisions that managers or other parties can make that affect the outcomes. Utility (or cost) nodes reflect the value of outcomes.

There are six chance nodes in this example: the actual state of the software development ("actual development progress"), with states "fair actual," "average actual," "good actual," and "very good actual"; the actual bug-infestation report ("actual bugs"), with states "none actual," "light actual," "medium actual," and "severe actual"; the bug-infestation status after allocation of additional effort, with states that correspond to the available actions (see the following); the state of the software at scheduled release time ("state of Release 1.0"), with the states from "actual development progress" plus "rotten," "bad," and "poor"; the observation of the development progress; and the observation of bugs.

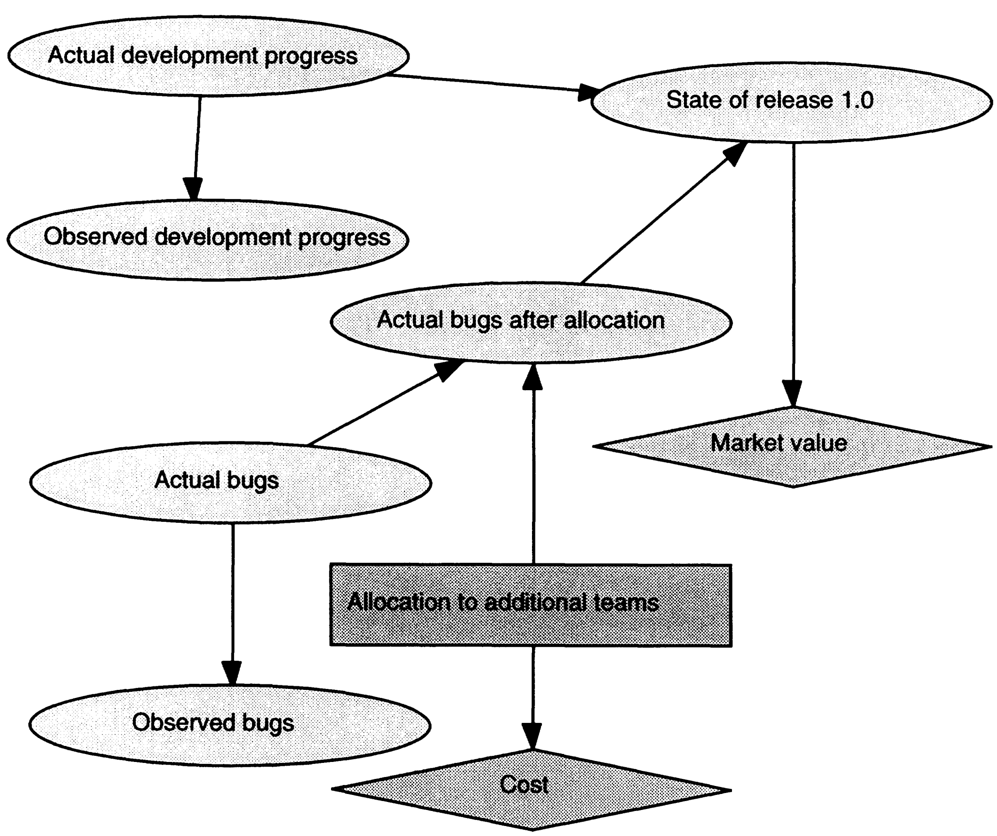
There is also an action/decision node, "allocation of additional teams," that models the decision to invest in extra development squads to deal with bug reports, with actions "no," "little," "moderate," and "heavy" investment.

Because the influence diagram has only one decision node, evidence can be entered into any chance node, and the Hugin software used to implement this example will calculate the expected utility of the decision options. That is, managers can speculate about how well they think development is proceeding and how likely bugs are and assess for those speculated conditions what the utilities are for each action they could take regarding allocation of additional resources to development.

Hugin Software Inputs

To analyze a problem such as the ACME situation, decision makers can translate the situation into the Hugin software package. As in Figure A1, multiple node shapes can exist.

FIGURE A1
ACME Software Influence Diagram



Elliptical nodes, such as "actual bugs," represent chance nodes. These nodes represent events that occur in the decision problem but have multiple possible outcomes that the decision maker cannot control directly. For example, "actual bugs" represents the actual level of bugs six months prior to the software's release. The likelihood of each state occurring is measured in terms of probability, summing to 1. If a chance node has no nodes directed into it, such as "actual bugs," it is called a "parent node," and its probabilities are based solely on each state's likelihood. For this case, the values of bugs are as follows: none actual .4, light actual .3, medium actual .2, and severe actual .1.

However, because the level of bugs observed is influenced by the actual number of bugs, the probability of each observed bug level, given the actual bug level, must be estimated. For example, the conditional probability matrix in Table A1 might be estimated (on the basis of research or prior experience).

Table A1 should be read so that the cell entry reflects the probability of observing the row condition given the column state. Given a medium level of actual bugs, there is a .1 probability of observing no bugs, a .2 probability of observing light bugs, a .5 probability of observing medium bugs, and a .2 probability of observing severe bugs. The .1 probability of observing light bugs when there are no actual bugs reflects that bugs may be observed in error or become "features" of the final release. Note that the Hugin software's use of conditional independence enables the decision maker to limit the consideration of node influences to those directly connected to a given node or parent nodes. All other information leading into the parent nodes already is reflected in the chosen probabilities.

The marginal probabilities reflecting the likelihood of the state of progress in overall software development must be estimated (on the basis of research or prior experience), as follows: fair actual .2, average actual .4, good actual .3, and very good actual .1. The conditional probabilities of observed progress, given the actual progress, also must be estimated (on the basis of research or prior experience), as in Table A2.

Rectangular nodes represent decisions that are controlled entirely by a decision maker. These decisions take place within the context of the situation. For example, the decision node "additional allocation to teams" represents the decision by ACME to increase its manpower commitments by none, little, moderate, or heavy amounts. Diamond-shaped utility nodes contain values for the utilities for each possible outcome. Therefore, decision nodes interact with uncertain chance nodes to create a level of expected utility given a specific decision. For the utility node "additional allocation to teams," the associated costs are estimated as follows: none 0, little –2, moderate –3, and heavy –4.

For the market value of the various outcomes, the following states of Release 1.0 are estimated: rotten –1, bad 1, poor 5, fair 8, average 10, good 12, and very good 13. To complete the example, the conditional probabilities in the final two chance nodes, "actual bugs after allocation" and "state of Release 1.0," must be estimated. The conditional probabilities in any chance node reflect the combinations of the states for all the nodes pointing directly in it. "Actual bugs after allocation" has states "none after," "light after," "medium after," and "severe after." The conditional likelihood of these states given the direct influences on them must be estimated from research or prior knowledge, as in Table A3.

The final set of conditional probabilities reflects the state of software of Release 1.0 given the actual state of progress

TABLE A1
Conditional Probabilities of Actual Bugs

	None Actual	Light Actual	Medium Actual	Severe Actual
None observed	.9	.2	.1	0
Light observed	.1	.5	.2	.1
Medium observed	0	.2	.5	.3
Severe observed	0	.1	.2	.6

TABLE A2
Conditional Probablilities of Actual Development Progress

	Fair Actual	Average Actual	Good Actual	Very Good Actual
Fair observed	.8	.3	.1	0
Average observed	.15	.6	.2	.1
Good observed	.05	.1	.6	.4
Very good observed	0	0	.1	.5

TABLE A3
Conditional Probabilities of Actual Bugs with Allocation of Teams

	None Actual	Light Actual	Medium Actual	Severe Actual
No Allocation of Additional Teams				
None after	1	0	0	0
Light after	0	1	0	0
Medium after	0	0	1	0
Severe after	0	0	0	1
Little Allocation of Additional Teams				
None after	1	.8	0	0
Light after	0	.2	.8	0
Medium after	0	0	.2	.8
Severe after	0	0	0	.2
Moderate Allocation to Additional Teams				
None after	1	1	.8	0
Light after	0	0	.2	.8
Moderate after	0	0	0	.2
Severe after	0	0	0	0
Heavy Allocation to Additional Teams				
None after	1	1	1	.8
Light after	0	0	0	.2
Moderate after	0	0	0	0
Severe after	0	0	0	0

in development and the actual state of bugs after additional allocation of development teams. These appear in Table A4.

These conditional probabilities, costs, and market values reflect essentially the default conditions (i.e., the best baseline guess of what is going to happen). If the network is compiled (using the "Compile" button) at this point, the marginal probabilities associated with each state of the chance nodes and the utilities associated with each possible action under the default conditions are revealed. The probabilities and utilities appear in Table A5. Note that the maximum utility (8.20) is associated with the decision not to allocate addition teams to the development effort. Much of the value of this approach lies in the ability to update understanding as new information becomes available. Say fair development progress is observed but so is a severe bug level. This evidence can be entered easily into the probability table and propagated through the network (using the "Sum Propagate" button). The probabilities and utilities appear in Table A6. Note that the maximum utility is much lower (4.81) and is associated with the decision to make a heavy allocation of additional development teams. In a similar fashion, the consequences of observing any conditions can be propagated through the network to help indicate the best actions to take and the likely market consequence.

This example can be extended by adding a later decision point on delaying the release date by one or more months.

TABLE A4
Conditional Probabilities of Bugs with Actual Allocation of Teams

	Actual Fair	Actual Average	Actual Good	Actual Very Good
No Bugs After Additional Allocation				
Rotten	0	0	0	0
Bad	.05	0	0	0
Poor	.1	.05	0	0
Fair	.7	.1	.05	0
Average	.1	.7	.1	.1
Good	.05	.1	.7	.2
Very good	0	.05	.15	.7
Light Bugs After Additional Allocation				
Rotten	.05	0	0	0
Bad	.1	0	0	0
Poor	.7	.05	.05	0
Fair	.1	.1	.1	.05
Average	.05	.7	.7	.15
Good	0	.1	.15	.7
Very good	0	.05	0	.1
Moderate Bugs After Additional Allocation				
Rotten	.15	.05	0	0
Bad	.7	.1	.05	0
Poor	.1	.7	.1	.05
Fair	.05	.1	.7	.1
Average	0	.05	.1	.7
Good	0	0	.5	.15
Very good	0	0	0	0
Severe Bugs After Additional Allocation				
Rotten	.9	.15	.05	0
Bad	.1	.7	.1	.05
Poor	0	.1	.7	.1
Fair	0	.05	.1	.7
Average	0	0	.05	.1
Good	0	0	0	.05
Very good	0	0	0	0

TABLE A5
Default Probabilities and Utilities

Actual Bugs	
.4	None Actual
.3	Light Actual
.2	Medium Actual
.1	Severe Actual

Actual Bugs After Allocation	
.72	None After
.16	Light After
.08	Medium After
.03	Severe After

Actual Development Progress	
.2	Fair Actual
.4	Average Actual
.3	Good Actual
.1	Very Good Actual

Observed Development Progress	
.31	Fair Observed
.34	Average Observed
.27	Good Observed
.08	Very Good Observed

Observed Bugs	
.44	No Observed
.24	Light Observed
.19	Medium Observed
.13	Severe Observed

State of Release 1.0	
.01	Rotten
.04	Bad
.09	Poor
.18	Fair
.34	Average
.23	Good
.10	Very Good

Utility of Allocation	
8.20	No Allocation
7.29	Little Allocation
7.04	Moderate Allocation
6.26	Heavy Allocation

The Project Action Web site (http://164.67.164.88) discusses this extension and provides the actual networks used in this Appendix.

TABLE A6
Probabilities and Utilities Assuming Fair Observed Progress and Severe Observed Bugs

Actual Bugs	
—	None Actual
.23	Light Actual
.31	Medium Actual
.46	Severe Actual

Actual Bugs After Allocation	
.39	None After
.26	Light After
.21	Medium After
.14	Severe After

Actual Development Progress	
.52	Fair Actual
.39	Average Actual
.10	Good Actual
—	Very Good Actual

Observed Development Progress	
* 1	Fair Observed
—	Average Observed
—	Good Observed
—	Very Good Observed

Observed Bugs	
—	No Observed
—	Light Observed
—	Medium Observed
* 1	Severe Observed

State of Release 1.0	
.10	Rotten
.15	Bad
.21	Poor
.22	Fair
.23	Average
.06	Good
.02	Very Good

Utility of Allocation	
3.00	No Allocation
3.30	Little Allocation
4.72	Moderate Allocation
4.81	Heavy Allocation

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