Tools for Discontinuous Innovation Research and Development

Michael Ali (michael.ali@att.net)

Abstract:

Discontinuous (also known as "radical", "GameChanger™", or "disruptive") innovations literally "change the game" by transforming existing industries or creating new ones. Successful discontinuous innovations yield significant profits for the winners and significant losses, even bankruptcy, for the losers. In Part I of this paper we give an overview of discontinuous innovation, including a data on some notable successes and failures. In Part II, we describe several tools to aid in the successful execution of discontinuous innovation R&D efforts. The author developed two of these tools, the Business Model Maturity checklist and the Maturity-Readiness Map. The other tools are taken from the existing literature and applied to the specific needs of discontinuous innovation R&D. In Part III, we provide some starting points for implementing the ideas in this paper.

1.0 INTRODUCTION

1.1 Discontinuous Innovation: Definition

Discontinuous (also known as "radical", "GameChanger ™", or "disruptive") innovations create such dramatic change that they transform existing industries or create new ones. Such an innovation generally does one or more of the following (Leifer):

a) create an entirely new set of performance features.
b) improve performance by 5x or more
c) significantly reduce cost (30% or more)

Christensen (2003) points out that the market for discontinuous innovations is often characterized by:

a) a user population with unmet needs or needs that are met in an inconvenient way
b) low-end customers who will accept “good-enough” performance at a lower price.

In Table 1, we provide data on several discontinuous innovations including Kodak film, radial tires, dry-cell batteries, the F-117 Stealth bomber, and the microwave oven.

1.2 Rewards of Discontinuous Innovation

The rewards of successful discontinuous innovation efforts are dominant market share and profits. Referring to Table 1, the “Impact/Benefits” column details how the discontinuous innovations affected both the developer and the competition. Disposable diapers, first introduced by Procter & Gamble, decimated cloth diaper service providers. P&G owned the market for this product from the 1960's to the mid-1980's. Film photography (by Kodak) eliminated glass plate photography, although it took over 15 years to do so. Stealth bombers, first used during Desert Storm, essentially ignored Iraqi surface-to-air batteries, bombing their objectives with zero losses. Finally, machine-made ice eliminated the pond-ice harvesting industry, and was in turn replaced by electromechanical refrigeration.

1.3 Risks of Discontinuous Innovation

The rewards of successful discontinuous innovation are great, but the risks are greater. Consider the many supposed discontinuous ideas that have failed (at least to date): pen computing, bubble memory, digital audio tape, and many others. As an example, consider white LEDs, given in Table 1. White LED’s were introduced in the early 1990's. They had the promise of eliminating incandescent and fluorescent lights. However, one estimate is that another 5 years are needed before cost/performance issues are resolved for these general applications (Hara).

There are a number risks associated with discontinuous innovation:

- ***Misleading customer input:*** Clayton Christensen (1997 & 2003) provides several examples where companies focused on meeting customer needs ignored the discontinuous innovations that put them out of business. The story of radial tires (see Table 1), fits this pattern (Gale). Uniroyal and Firestone ignored the threat of radial tires, developed by Michelin, because the U.S. automakers did not want them. When the market finally recognized the superior characteristics of radial tires, neither manufacturer was able to compete. Michelin bought Uniroyal, and Bridgestone bought Firestone. Zangwill (1993) lists other ways that customer input can be misleading:
  - customers cannot express what they want
  - customers may not know enough to be helpful
  - customers may not identify a problem if they believe no solution is available for it
  - customer wants may change by the time the product is available
  - many people may be involved in the purchase, each with different requirements.
- ***The market is not known***: The "killer application" (i.e., the application that drove demand) for dry cell batteries was the flashlight, which did not exist when dry cell batteries were first developed. Recognition of this market led the National Carbon Company to buy the Ever Ready flashlight company and adopt the name "EverReady" for its batteries (Woehbler).
- ***Years of investment may be required*:** Xerox estimates an average of 8 years before breakeven on any innovation projects, not including the time and money spent in the R&D phase (Wolpert). Other sources list the lead-time for "new knowledge" innovations as 50 years (Drucker, Mhatre). Referring to the "Time(s)" column in Table 1, note that in several cases (film photography, microwave oven, radial tires), the time between initial concept and market success was *decades*.
- ***Inadequate supply chain*:** Hoover had no luck with selling vacuum cleaners until he created his famous door-to-door sales force (Gershman). Polysack had to train clerks to use their plastic grocery bags (Gale). Discontinuous innovations can change the game across the supply chain, but the supply chain may not be ready to have the game changed.

Discontinuous development is therefore inherently riskier than incremental development. While most R&D organizations tend to focus on the technical risks associated with discontinuous innovations, the list above shows that another set of problems are at least, if not more, important. We classify these problems, which include unknown markets, inadequate supply chains, and misleading customers, as *business model* risks. In the next section we provide a framework for analyzing business model risk. This framework is used by two of the tools discussed in Part II: the Business Model Maturity Checklist and the Maturity-Readiness Map.

1.4 Business Model Framework

Taking a truly game changing innovation to market requires overcoming many areas of risk. Risks can be external to the organization in the form of customers, suppliers, and/or distributors who are not prepared for the innovation. Risks can also be internal, in the form of incompatible business direction and inadequate allocation of resources. We refer to these issues collectively as *business model* risks. Our description of a business model uses a framework developed by Hamel (2000)(see figure 1.4.1).

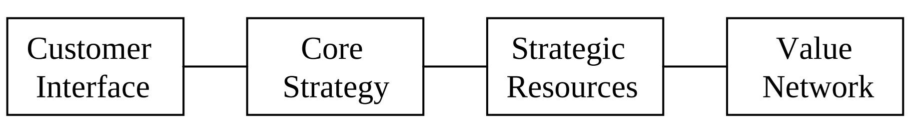

Figure 1.4.1 Business Model Framework

In this model, we see 4 major components:

1) **Customer Interface:** concerned with fulfillment and support of the customer, as well as maintaining and intimate knowledge of customer needs and the value to them of having those needs fulfilled.
2) **Core Strategy:** concerned with mission and goals of the business, how they relate to the market, and how differentiation of the business from the competition is maintained
3) **Strategic Resources:** concerned with the core competencies of the business and the assets (people, process, technology) that form those competencies
4) **Value Network:** the relationships with vendors, suppliers, competitors, partners, associations, etc required to bring the product/service to market

As a quick example of the usefulness of this framework, we used it to classify the innovations in Table 1 (see the columns under "Business Model Maturity"). Using the framework, we judged each innovation as to whether its business model was "new" or "existing" in each of the four areas above. Example: Hoover had to train a door-to-door salesforce for his vacuum cleaners. Clearly, this represented a "new" Value Network in his business model. Example: L'Oreal is experimenting with a skin moisture sensor for assessing the right cosmetics to use with a particular customer. This represents a "new" Customer Interface for L'Oreal.

1.5 Summary

In Part I of this paper, we have defined discontinuous innovation. We provided several examples (Table 1) of both successful and unsuccessful discontinuous innovations. Using this data, we identified a key risk in discontinuous efforts: *business model* risk. We presented a framework that allows us to systematically analyze business model risk. In Part II, we demonstrate several tools that leverage this framework to reduce business model risk.

Table 1. Discontinuous Innovations Data

Innovation	Business Model Maturity				Time(s)	Impact/Benefits	Comment	Reference
	Customer Interface	Core Strategy	Strategic Resources	Value Network				
3G Mobile Networks (various)	new	exists	exists	exists	2000: described as the Next Big Thing	No major benefits realized to date. Potential: eliminate current networks.	Radical business model needed: "[3G] must be good at saving and killing time". Video-streaming kills battery life in hand-helds.	Yoshida
Dry-cell Battery (National Carbon Company, EverReady, Energizer)	new	exists	exists	exists	1887: 1st dry cell 1896: 1st US dry cell by NCC (later EverReady, now Energizer) 1898: flashlight invented	Energizer is now #2 to Duracell, who is considered the more innovative and savvy marketer.	The American Ever Ready flashlight was the non-obvious "killer app" for dry cell batteries. National Carbon Company (NCC) bought American Ever Ready in 1914.	Woehbler
Electric Car (Fuel Cell driven, ex: Hy-Wire by GM)	exists	exists	new	exists	1932: 1st prototype cell 1959: 1st vehicle (tractor) 1999: 1st full-size vehicle 2010: volume car builds	No major benefits realized to date. Potential: eliminate gas engines, enable radical designs	GM's "skateboard" concept shows the radical combination of fuel cell and drive-by-wire technology. GM is building competencies to take advantage of the new paradigm.	HY-Wire, Fuel Cell Today, Ealy, Murray 2003
Fuel Cell for laptops and phones (MTI, Smart Fuel Cells GmBH, Manhattan Scientific)	new	exists	exists	exists	1932: 1st prototype cell 1960: spaceflight applications (GE, P&W) 2002: 1st production pilots for consumer apps	No major benefits realized to date. Potential: 10x advantage over today's laptop & phone batteries	Laptop market requires robustness to temperature extremes. Recharging today's batteries is "free", fuel cells require purchase of fuel (methanol).	Gaertner, Herper, Murry 08/12/02, Murray 5/26/03
F-117 Stealth (Lockheed-Martin)	exists	exists	new	exists	1962: Russian paper 1975: paper discovered 1977: 1st prototype 1981: 1st production (target was 1980)	Saved Lockheed-Martin, victory in Desert Storm. 100:1 reduction in radar x-section.	Air Force had to develop new training and mission capability. Lockheed had to develop new assembly techniques and new coatings.	Rich
Film photography (Kodak)	new	exists	exists	exists	1860: invention of celluloid 1889: 1st use in cameras 1902: Kodak has 90% of mkt	Eventually eliminated the glass plate photography industry (took 15-25 years).	Market took off when focus shifted from marketing to professionals to marketing to amateur photographers.	Utterbach
Fingerprint sensor used to measure skin moisture (STMicro and L'Oreal)	new	new	exists	exists	2000: initial meeting 2002: product	No major benefits realized to date. Potential: change the way cosmetics are developed and sold.	L'Oreal: customer interface is radical ST Micro: Core Strategy is radical relative to biometrics.	Murray 10/21/02
Ice making (various)	new	exists	exists	exists	1834: 1st practical device 1879: 30 plants in Southern states	Killed the ice-harvesting industry by the mid-1920's. Replaced in turn by refrigerators.	Pond-ice was cheaper than machine-made ice at first. Had to start in the South where prices of pond-harvested ice was higher.	Utterbach

Table 1 (continued). Discontinuous Innovations Data

Innovation	Business Model Maturity				Time(s)	Impact/Benefits	Comment	Reference
	Customer Interface	Core Strategy	Strategic Resources	Value Network				
Microwave Oven (Raytheon)	new	exists	new	new	1947: 1st commercial model 1955: 1st home model. 1968: 1st countertop model 1971: 1% US households 1986: 25% US households	Today, 90% of US households have a microwave oven.	First models were large, expensive ($1000+), and water-cooled. Cost had to be reduced to $500, which required technical innovation to reduce voltage and allow air cooling. Home economists were hired to train customers.	Gershman, Liegey
Nanotechnology: whiskers embedded in fabric (Nano-tex) for stain resistance	exists	new	new	exists	1998: 1st mtg 2000: 1st product 2001: 1st scale production	Burlington still went into Chapter 11. Potential: eliminate existing fabrics via better stain resistance.	New strategy and resources for Burlington. Business model innovation: license technology to other mill owners.	Fitzgerald, Nano-Tex
Pampers Disposable Diapers (Procter & Gamble)	new	exists	exists	exists	1957: go decision 1961: patent filed 1962: 1st production 1976: 50% of US babies use Pampers	Diaper service providers dropped from 400 in the 1980's to 50 in 1998. P&G was #1 until 1985. Now Kimberly-Clark (41.5% vs. 40.4% for P&G)	Changes sales pitch to mothers from "no more washing diapers" to "drier, happier babies". Originally, focus was on cost-- keep same as cloth. Now disposables cost more.	Gershman
Polysack: plastic grocery bag (Sonoco)	new	exists	exists	exists	1980: 1st production 1984: sales of $16M 1988: sales of $105M	By 1996: 4 out of 5 grocery bags used are plastic (plasticbag.com)	Had to train grocers to use bags and engage line management rather than Purchasing in the decision to use. Realization that plastic bags helped speed up checkout.	Gale
Radial Tires (Michelin)	exists	exists	exists	new	1946: patent issued 1970: Ford uses for Continental MkIII	From 3% to 30% of tire market in 3 years. Uniroyal bought by Michelin, Firestone sold.	Key was Ford designing its cars to ride properly with radials.	Gale, Michelin
Vacuum Cleaner (Hoover)	exists	exists	exists	new	1901: prototypes 1907: rights purchased by Hoover 1910: 2000 sold 1920: 273,000 sold	Hoover became a $700M company before it was purchased by Chicago Pacific in 1985 and Maytag in 1989.	Tried different distribution channels. Had to be sold by direct sales force to facilitate husband-wife joint decision. Another limitation was the US households with electricity (10% in 1910, 30% in 1920.	Gershman
White LEDs (various)	new	exists	exists	exists	1996: 1st white LEDs 2002: Expect another 5+ years to address cost & performance issues	No major benefits realized to date. Potential: eliminate incandescent bulbs.	Need to be more radical with business model. Currently cost 10x-30x incandescent lamps. Used as backlights in consumer electronics.	Hara

2.0 Tools for Discontinuous Innovation R&D

In this section we introduce tools for reducing the Business Model Risk of discontinuous R&D efforts:
1. the Business Model Maturity rating scale
2. the Discontinuous Innovation R&D Process
3. the Business Model Maturity-Technology Readiness Map (Maturity-Readiness Map)
4. the Customer Value Map
5. TRIZ Guided Technology Evolution
6. the Market Adoption to Business Model Map

2.1 Business Model Maturity Rating Scale (figure 2.1)

This checklist was derived from the Business Model framework in Section 1.4. Recall that the model consisted of four parts: Customer Interface, Core Strategy, Strategic Resources, and Value Network. The checklist below uses these to identify areas of risk for a proposed discontinuous development effort. Risk is where the business model is either “new” or “unknown”. Note that "existing", "new", or "unknown" is *relative to the entity or entities bringing the discontinuous innovation to market*. An example would be an innovation for the automotive industry: if the company marketing the innovation was new to the industry, then the business model will be "new", even though the auto industry itself is decades old. The output from the Rating Scale is used in the Maturity-Readiness Map (Section 2.3).

Instructions: Given the business model for a proposed innovation, indicate with an "x" in the appropriate column whether that part of the model is included in the organization's current business model, is new to the organization, is unknown, or is not applicable. Sum the "x's" in each column in the "Totals" row. Use the totals and expert opinion to make the overall assessment of the proposed business model.	Exists	New	Unknown	N/A
I. Customer Interface				
1. Experience with fullfillment and support of customer				
2. Mechanisms to gather information and insight				
3. Knowledge of relationship dynamics				
4. Understanding of pricing structure				
II. Core Strategy				
5. Business mission consistent with business model				
6. Experience in scope of market				
7. Basis of differentiation from competition				
III. Strategic Resources				
8. Core competencies in business model				
9. Strategic assets ready to support business				
10. Core processes ready to support business				
IV. Value Network				
11. Relationships with necessary suppliers				
12. Relationships with necessary partners				
13. Relationships with necessary coalitions				
TOTALS				
OVERALL ASSESSMENT (Exists, New, or Unknown)				

Figure 2.1 Business Model Maturity Rating Scale

2.2 The Discontinuous Innovation R&D Process

In contrast with conventional New Product Introduction (NPI) processes, discontinuous innovation R&D has special concerns. In conventional NPI, the markets, customers, and value chain are well known. In most cases, quantitative estimates can be generated for the price elasticity of demand, competitive responses, etc. The design team on an NPI project can therefore follow a straightforward process from concept to market. For discontinuous innovations, this information may be completely unknown. From Table 1, consider the dry cell battery. A team designing batteries at the National Carbon Company in 1896 would have faced a number of difficult problems. Since the final applications were not known, there was no way to get input on what capacities were needed. There were no standard sizes, so the battery dimensions were not constrained. There was no demand for batteries, so price elasticity did not exist. The developers of the other gamechanging innovations in Table 1 had similar issues. Discontinuous innovation R&D requires a different kind of process than conventional NPI.

In his book "Leading the Revolution", Gary Hamel introduces a process for business model innovations that consists of four steps: Imagine, Experiment, Assess, Scale. We have adopted his model for discontinuous innovations with one change: the final step may be one of several options, which includes scaling up for production. As a result, we changed the last step from "Scale" to "Transition". In the table below, we compare the conventional NPI process steps to the discontinuous innovation steps.

Step	Conventional NPI Process	*Discontinuous R&D Process*	Differences, Discontinuous Innovation vs. NPI
1.	Market Research	***Imagine***	Customers/market may not understand the innovation. Team must use imagination to envision uses. Do "needs based" as opposed to "product based" customer studies (Christensen 2003).
2.	Design	***Experiment***	Significant uncertainty around the features and attributes needed for a successful product. Design should include "hooks" for easy addition/deletion of features. Customer research should test radically different concepts at first. The business model must also be experimented with.
3.	Build & Test	***Assess***	Selection between various designs and business models must include robustness in addition to profitability. The best business model may not be the most profitable, but rather the one that is the most robust to failed assumptions.
4.	Sell	***Transition***	Select from several options: commercialize via creating a new division, use existing division, spinout, license, continue with effort, or bookshelf.

2.3 The Maturity-Readiness (MR) map

2.3.1 Overview

Given the risks of discontinuous innovation R&D, it is important to correctly classify development efforts as discontinuous innovations or something else. The MR map (figure 2.2), developed by the author, takes the proposed innovation and classifies it based on the Readiness of the technology on which it is based, and the Maturity of the business model that will take it to market. Readiness is measured simply as time-- in this case the number of years needed to ready the technology for market. Maturity is measured using the Business Model Maturity Checklist (section 2.1). The MR map is separated into 3 zones: Basic Research, Discontinuous R&D, and Conventional New Product Introduction. Note that once the maturity and readiness is determined, the type of innovation is specified by the map.

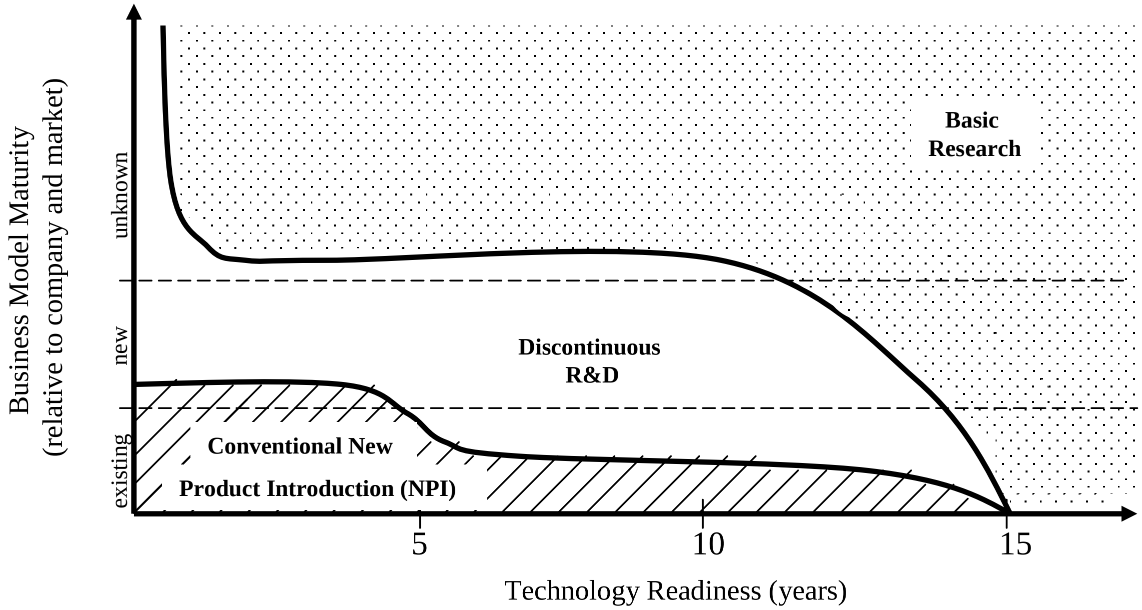

Figure 2.2 The Maturity-Readiness Map

The MR Map is the result of integrating and synthesizing information from a variety of sources. In Figure 2.2, we are postulating the map, the zones, and boundaries of those zones. One area of future research would be to validate the map using data from one or more companies in a specific industry.

2.3.2 Zones on the Maturity-Readiness Map

Conventional New Product Introduction (NPI) Zone

An innovation in this zone has a well-understood business model. The innovation is taken to market by the normal NPI process used by the organization. In Christensen (1999, 2003) this type of innovation would be called "sustaining" as opposed to a discontinuous. An interesting feature of the NPI zone is the inflection point at approximately five years. As the time market increases, the reliability of the business model decreases. The MR Map recommends using a Discontinuous R&D process to reduce the uncertainty in the business model.

The Discontinuous R&D Zone

In this zone we need the Discontinuous Innovation R&D Process (section 2.2) to take the innovation to market. Two areas of note are the extreme left and far right of the boundary. To the left, the boundary rises asymptotically because Basic Research, the adjacent zone, does not take innovations to market. By definition then, the Discontinuous Innovation process must be used at some point, if the research project is to have an associated business model. To the right, the boundary drops sharply until it ends at 15 years. We postulate the 15 year mark as the limit of validity for using the discontinuous innovation process. After that point, any work on an innovation must be done with a research mindset. The 15-year mark is an average across several industries. Given that the market clock ranges from months for computer technology to decades for automobile engine technology (Fine), the actual endpoint is industry-specific.

Basic Research Zone

The basic research zone is anything not covered by the NPI and Discontinuous zones. Research is characterized by long time periods of technology development coupled with little to no knowledge of how the results of the work will be commercialized. We recommend using the MR Map to identify research projects that may be masquerading as discontinuous or NPI projects, and set expectations accordingly. A good example is fuel cells for automotive use. Significant expectations are being set around the viability of this technology for use in vehicles. Most expert opinion is that the remaining hurdles (technical, regulatory, value chain, etc) will require decades of effort to resolve (Murray, 2003). Based on the MR Map analysis, our recommendation would be to treat these efforts as research.

2.3.3 Example use of the Maturity-Readiness Map

In Figure 2.3, we place several of the innovations from Table 1 onto the MR Map. The logic behind the placement can be inferred from the data, including the comments, in Table 1. As an example, we place Kodak film at 15+ years on the horizontal and in the "new" section of the Business Model Maturity axis. Amateur photography was the "killer app" that caused Kodak's innovation to succeed. However, when Kodak first conceived of his innovation, amateur photography did not exist. Therefore, the market and the business model required to exploit it, was "new". The location on the Readiness axis is based on the time between the invention of celluloid film in 1860, and its first use in cameras in 1889 (15+ years).

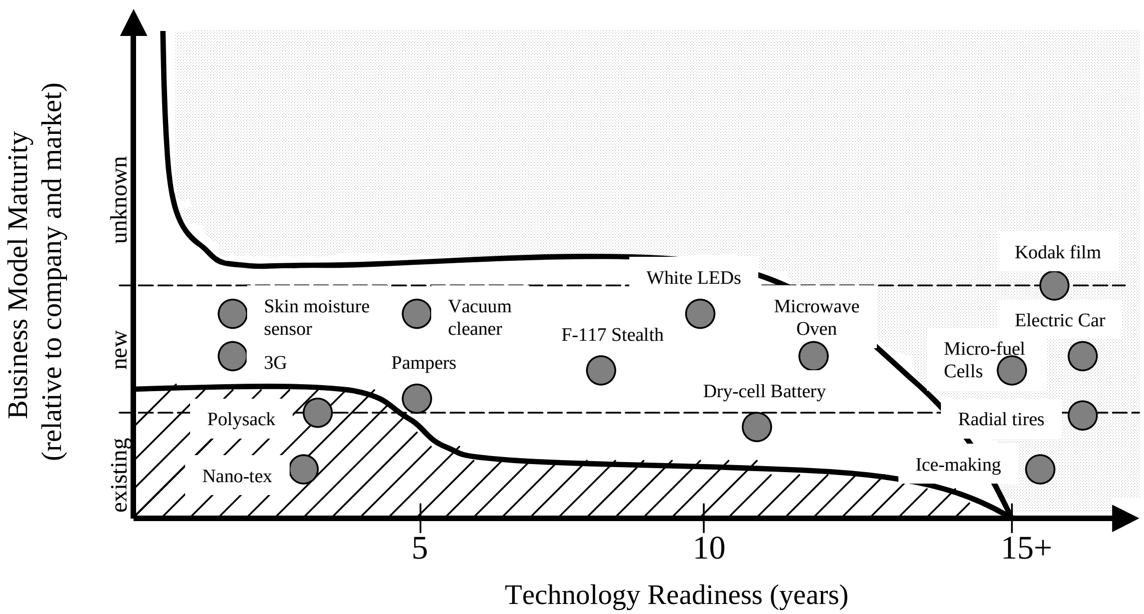

Figure 2.3 Discontinuous Innovations from Table 1 placed on Maturity-Readiness Map

2.3.4 Trajectories on the Maturity-Readiness Map

The MR Map is not just a tool for fixing an innovation in maturity-readiness space. Once we have a starting point on the map, we can generate a path by following the Readiness axis to the left. As the trajectory is created, options arise as to whether or how to cross the boundaries between zones. In Figure 2.4, we show a typical case: an innovation developed as a research project is taken to market. We see there are two categories of paths. One category of path (Trajectory 1) moves the innovation to market by transitioning from Research to Discontinuous R&D. Another class of trajectory (Trajectory 2) consists of taking the innovation to market using the Discontinuous Innovation R&D process to first reduce the uncertainty in the business model, then use the conventional NPI process to go to market

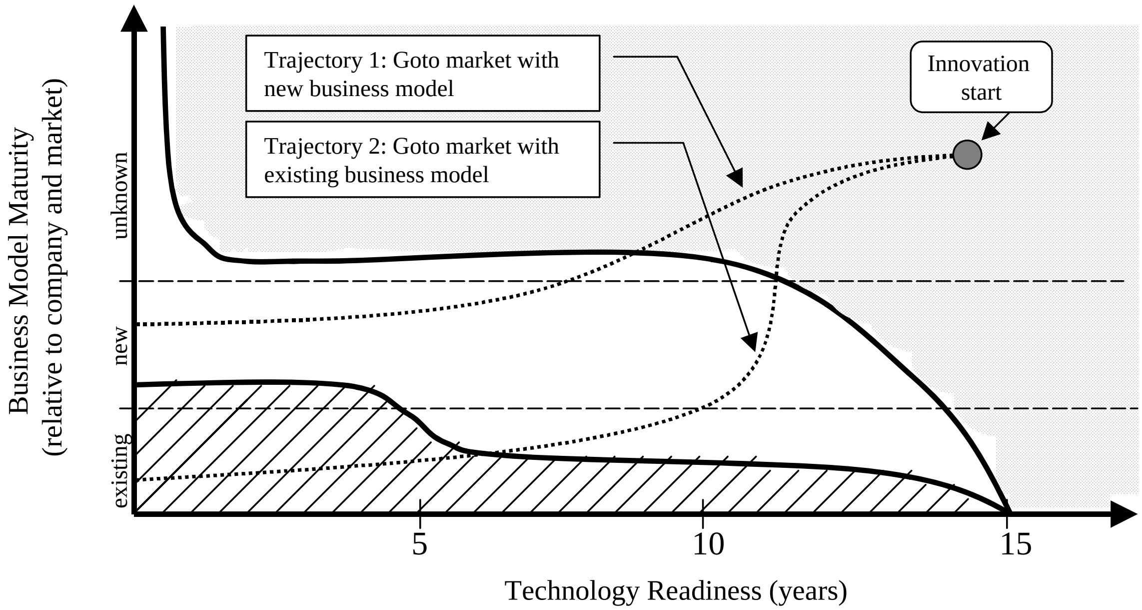

Figure 2.4 MR Map Trajectories: typical cases

Figure 2.5 shows some other types of trajectories. In figure 2.5, circle "A" shows that an innovation may start as a conventional NPI, and then, based on information discovered during the execution of the project, require the Discontinuous Innovation process to go to market with a new business model. The trajectory starting with circle "B" shows a series of technical issues, which impacts technology readiness, being resolved before commercializing the innovation using a new business model.

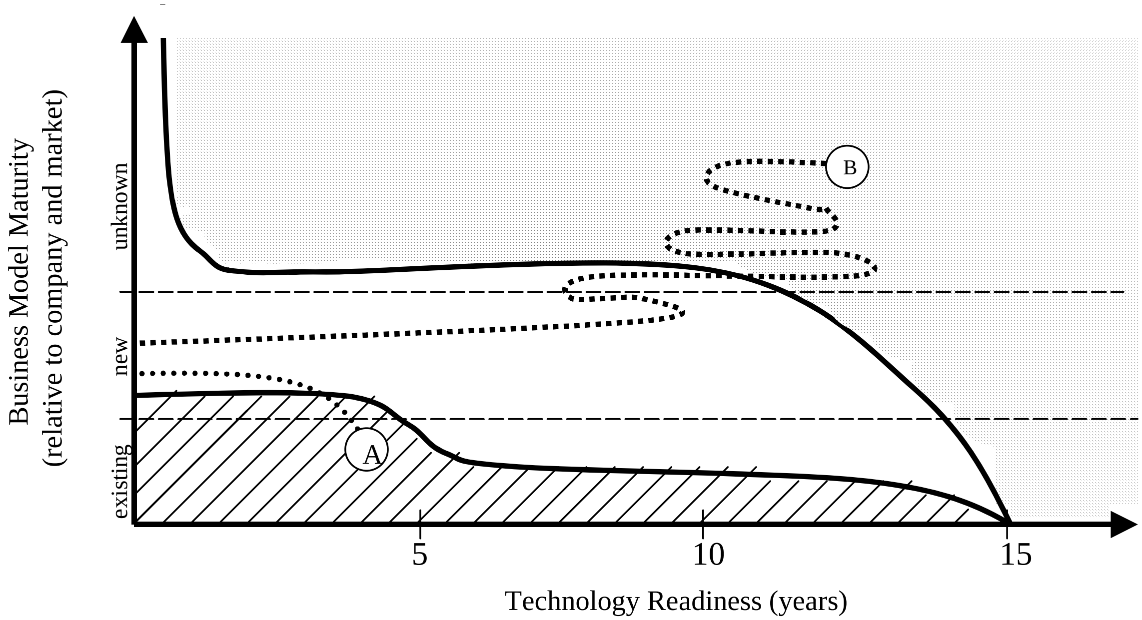

Figure 2.5 MR Map Trajectories: other cases

2.4 Customer Value Map (Gale)

This tool is a powerful way to assess a proposed discontinuous innovation against the competition. As seen in the figure below, the Customer Value Map has three essential features: the vertical axis, which is the price ratio between the two products, the horizontal axis, which is the "quality" ratio between the two products (where "quality" includes functionality), and the Fair Value Line which defines the trade-off between price and quality that the market is willing to make. The space above the Fair Value Line represents a bad deal for the customer (price is high relative to quality). The space below the Fair Value Line represents a good deal for the customer (price is low relative to quality). The preference is for a given product to map into the space below the Fair Value Line because it has a higher Perceived Quality at a lower Relative Price.

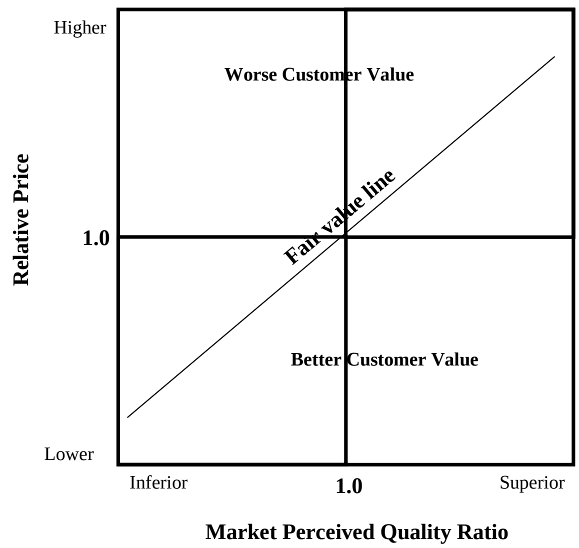

Figure 2.6 Customer Value Map (Gale)

The use of this map for discontinuous R&D is best shown by example. Micro fuel-cells are being developed for the laptop market (Gaertner, Herper, Murray Dec. 2002, and Murray 2003). The vision is that micro fuel-cells have higher energy density that the Lithium-Ion batteries used today. We will develop the Customer Value Map comparing micro fuel-cells against Lithium-Ion rechargeable batteries (refer to Table 2.2):

1. First the relative price of the two technologies is compared. The initial purchase price is the same, therefore the relative prices are equivalent (we gave them each a score of 5 out of 10 points). The cost of recharging is significantly different: the micro fuel-cells will cost a dollar or so for the purchase of fuel (Johnson). Lithium-Ion recharging is essentially free. Therefore the score is 8 out of 10 for Lithium-Ion vs. 2 out of 10 for micro fuel-cells.
2. We make an assumption that users would weight the initial purchase price slightly higher (60) than the recharge price (40).
3. We then multiply the appropriate weight by the price ratios between each battery and add the amounts to compute a total score for the relative price. We then normalize the score by dividing by 100. The results are 0.7 ([60*5/5 + 40*2/8]/100) for micro fuel-cells and 2.2 ([60*5/5 + 40*8/2]/100) for Li-Ion. Clearly, Li-Ion is cheaper (lower Relative Price Ratio) for the customer.
4. The perceived quality scores are computed in a similar way. For quality, we use two criteria, time between charges and time to charge. The fuel-cells score better than Li-Ion on both these criteria.

	Importance Weights	Li-Ion (1-10)	Fuel Cell (1-10)	Li-Ion Score	Fuel Cell Score
Market Perceived Quality					
Time between charges	60	4	8	30	120
Time to full charge	40	4	8	20	80
TOTAL				50	200
Perceived Quality Ratio				**0.5**	**2.0**
Relative Price					
Purchase price	60	5	5	60	60
Recharge price	40	8	2	10	160
TOTAL				70	220
Relative Price				**0.7**	**2.2**

Table 2.2 Customer Value Map Data

5. Finally, we use the price and quality scores to map the two technologies. Using the two ratios from the table, the Li-Ion battery is plotted at (0.5,0.7), and the Fuel Cell is plotted at (2.0,2.2). The results are shown in Figure 2.7.
6. The last step is to assess the two technologies relative to the Fair Value Line. In the absence of actual market data, we investigate three scenarios: one where battery performance (i.e., quality) is more important than price (the line labeled "Q>P"), one where performance is equally important to price ("Q=P"), and one where battery performance is less important than price ("Q<P"). Note that fuel-cells are better (i.e., below the Fair Value Line) in 2 out of 3 cases. Lithium-Ion is the preferred choice when price is more important than quality.

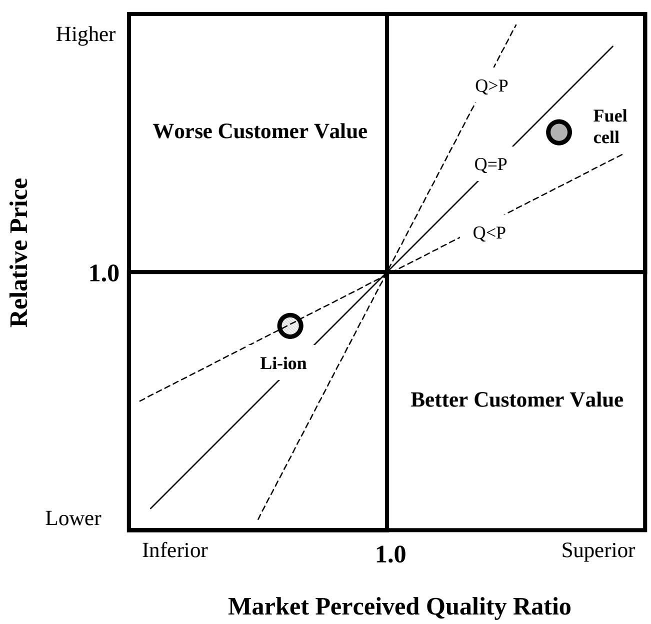

Figure 2.7 Customer Value Map: Micro Fuel-Cell vs. Lithium-Ion Battery

This simple analysis shows the power of the tool: we have quickly identified two critical issues that must be addressed by the micro fuel-cell manufacturers: the cost and effort associated with recharging, and how to identify customers that prefer longevity to cost (example: geologists who work in the remote areas). The interested reader is referred to (Gale) for further explanation and more examples.

2.5 TRIZ Guided Technology Evolution

TRIZ is an acronym based on the Russian words for "Theory of Solution to Inventive Problems". It was invented by G. Altshuller in the 1970's. TRIZ is fairly well known in the United States (www.triz-journal.com). One of the TRIZ tools is Guided Technology Evolution (Fey, Gahide). Guided Technology Evolution recognizes that product innovations often follow a similar evolutionary pattern: from the initial object to partial mobility to increasing mobility (or degrees of freedom), to flexibility, to molecular objects, and finally to the use of fields. The table below gives some examples.

Table 2.3 Examples of TRIZ Guided Technology Evolution

	cutting	**telescope**	**film**	**music player**	**vacuum cleaner**
Initial Object	axe	one lens, fixed	glass plate, fixed	phonograph, metal cylinders	original Hoover
Partial mobility of parts of object	-	moveable lens	removable plates	floating stylus	adjustable height
Increasing degrees of freedom	Double-blade axe, saw	multiple lenses	multiple plates	record changer, jukebox	powered wheels
Change to a flexible object	diamond wire cutter	elastomeric lenses	-	-	flexible hoses and bags
Change to a molecular object	waterjet cutter	liquid/gas lens	celluloid film	polyvinyl records	steam-vacs, wet-vacs
Change to a field object	laser	Field-adjusted liquid/gas lens	digital (CCD)	CD player	electrostatic filters

Guided Technology Evolution was originally intended for conceptualizing new inventions, however we can also use it to analyze the business model risk for given innovation. To do so, we first categorize the current state of the products in the market on the evolutionary scale. Then we categorize the proposed discontinuous innovation. Finally, we assess the evolutionary gap between the state-of-the-practice and the discontinuous innovation. The larger the gap, the larger the business model risk. Example 1: customers using axes to chop wood are less likely to understand the benefits of a laser cutter than customers using waterjets. Example 2: the support network (dealers, servicers) for Thomas Edison's original phonograph had very different training and skills than today's sellers and servicers of CD players. The core competencies needed for field-based innovations (CD player) are different than those needed for high degrees of freedom innovations (phonograph).

2.6 Market Adoption to Business Model Map

Geoffrey Moore has written several books (Moore, 1999, 2000, 2002) using his Market Adoption life-cycle model. Shown in the figure below, the model identifies 4 major stages in the life of an innovation. The Early Market is where the innovation first finds a customer base. In the Bowling Alley, the innovation finds a series of niches that build market share. Note the Chasm between the Early Market and the Bowling Alley—many innovations never make it across. If the Bowling Alley phase is successful, the innovation begins to build its market exponentially. This is called the Tornado Phase. Finally, once the innovation gains enough market share, it becomes a mainstream product on Main Street. At each stage, the business model and requirements for success vary dramatically. As an example the business model for a successful innovation in the Early Market is the opposite of that required for the Mainstream Market (see Table 2.4).

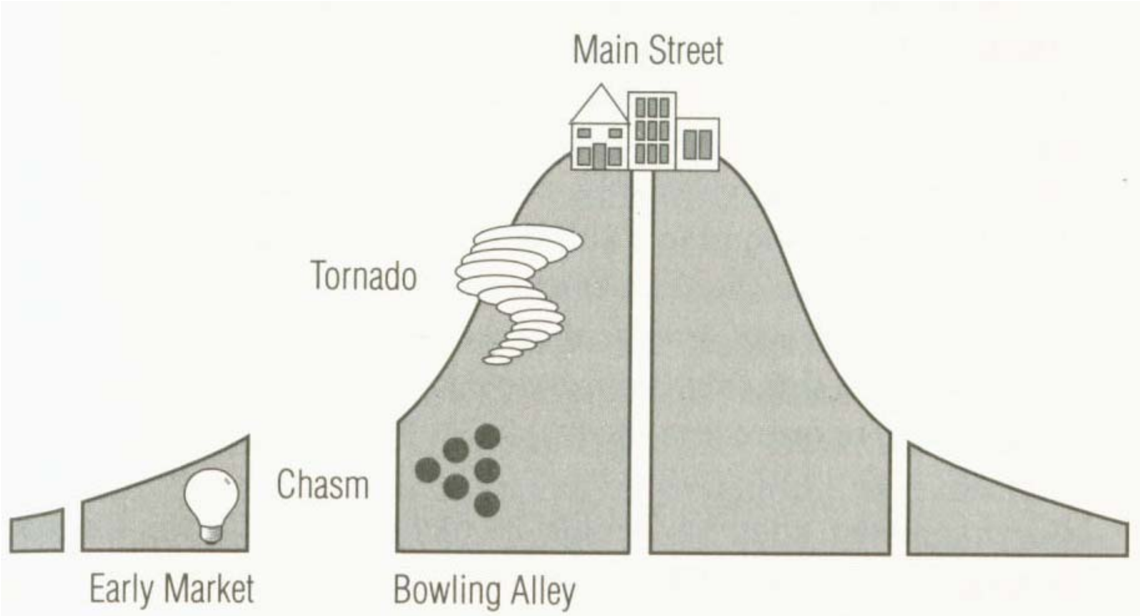

Figure 2.8 Technology Adoption Curve (Moore, 1999, 2000, 2002)

Table 2.4 Early Market vs. Main Street: customer expectations

	Early Market	**Main Street**
Features and attributes of product	Not sure who the customer is or what they want, include as many features as possible.	Reduce to the minimum to identify a clear position in the market.
Value-added resellers	Use them—they will configure the product for the customer	Eliminate them—added cost and complexity for the customer
Customization of the product	Customize as necessary to meet the needs of a particular customer	Never customize, be a commodity purchase.

Going further, we can identify which parts of our Business Model Framework (Section 1.4) are critical to particular stages of the Market Adoption life-cycle. This mapping creates the Market Adoption to Business Model Map shown in Table 2.5 below. As an example, in the Early Market phase, the Core Strategy and Value Network elements of the business model are critical. This map therefore identifies areas of focus for the business model, based on the life-cycle phase of the innovation.

Table 2.5 Market Adoption to Business Model Map

	Customer Interface	**Core Strategy**	**Strategic Resources**	**Value Network**
Early Market		X		X
Bowling Alley	X	X		X
Tornado		X	X	X
Main Street	X		X	X

3.0 Summary/Next Steps

In this white paper, we have established that discontinuous R&D is a high reward and high risk activity. Discontinuous R&D is also a distinct activity from conventional new product development and pure research. We have discussed several tools to aid discontinuous R&D efforts. Two new tools, the Business Model Maturity Checklist and the Maturity-Readiness Map, were introduced and shown to be valuable for visualizing the issues involved in discontinuous innovation efforts. A Discontinuous Innovation R&D process (Imagine-Experiment-Assess-Transition) was defined. Finally, we reintroduced some existing tools (Gale maps, TRIZ Technology Evolution, Market Adoption life-cycle) and showed how they can be used in new ways to support the discontinuous innovation process.

For next steps, we recommend the following:

a) Given the importance of the business model, create a Business Model Development team to complement the technology development team on a discontinuous innovation effort
b) Do a business model assessment for each of the projects in the R&D portfolio. Identify those with "new" requirements
c) Examine your R&D project portfolio and map it onto the Maturity-Readiness Map. Identify discontinuous innovations and apply the Imagine-Experiment-Assess-Transition process to them.
d) Identify existing discontinuous innovation efforts that are ready for the Transition phase
e) Establish a discretionary fund specifically for discontinuous efforts, since they will typically not meet the financial hurdles typically required for conventional new product development projects
f) Adjust the organization so that discontinuous innovation efforts have long-term champions (Pearson)
g) Experiment with different trajectories on the Maturity-Readiness Map, identify the trajectories that work best in your organization.

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