

Chapter 11

Assessing Technology Opportunities

11.1 ENTREPRENEURIAL ENGINEERS SEEK OPPORTUNITY

During the Cold War, there was a stark division of labor between business managers and the engineers who worked for them. Managers drove the business directions of the company, and engineers executed the design, manufacturing, and operational tasks managers assigned to them. Following the Japanese-inspired quality revolution, engineers have become more involved in pursuing and developing *opportunities* within and outside the organization.

To better understand the nature of opportunities and how to plan whether to exploit them or not, today's entrepreneurial engineer needs to understand, assess, and pursue opportunities, not only in terms of their technological feasibility, but also with a keen eye toward their business impact.

To do this, we examine the preparation of a *technology opportunity assessment* (TOA). TOA can be thought of as a miniature business plan (FastTrac, 2000). When an opportunity is potentially marketable (a marketable opportunity), a TOA is a preliminary step to preparing a more complete business plan. When an opportunity is viewed as largely helpful within an existing organization (an internal opportunity), a TOA is a preliminary step prior to investing significant funds in the idea.

To prepare a technology opportunity assessment, we need to consider:

- The opportunity
- Its competitive advantage, sustainability, and niche
- The economic case
- Preparation of the written TOA

The steps vary somewhat depending upon whether the opportunity is marketable or internal, but both types of opportunity should be subject to TOA scrutiny.

11.2 WHAT IS AN OPPORTUNITY?

Simply stated an opportunity may be defined as follows:

An opportunity is a correctable difference between the way things should be and the way things are.

Parsing the words carefully, we note that opportunities are fundamentally about *change*, in particular, possible changes that should make life, in some sense, *better* for one or more individuals. Moreover, opportunities are about changes that can be *realized*. On the one hand, recognizing opportunity is an act of imagination, but it is not an act of utopian dreaming. For something to be considered an opportunity, it must have a realistic chance of achieving the desired change in the state of the world.

There are a variety of ways of classifying opportunities. Opportunities may be classified depending upon their sphere of influence and modality of effect. Commercial or entrepreneurial opportunities may be classified depending upon their locus within the enterprise's value chain. Each of these is briefly discussed.

Sphere of Influence

Opportunities may be classified based on their primary sphere of influence:

1. Personal
2. Entrepreneurial
3. Commercial
4. Societal

Each of these is briefly discussed in what follows.

Personal opportunities affect our personal lives. A potential job or career change, meeting a new person and possibly making a new friend, or considering a move to a new city are examples of personal opportunities. Although the methods discussed here can certainly be used in evaluating personal opportunities, they are not our primary concern and are not discussed further.

Entrepreneurial opportunities are those that involve the creation of a new product or service. Sometimes the new product or service may be provided by an existing enterprise, but oftentimes, a new product or service is launched through the creation of a new business entity.

Commercial opportunities occur in the course of running an extant enterprise; they involve a change to an existing product or service or the organization itself in a way that may improve the enterprise's competitive position, profits, internal efficiency, or other measures of commercial success.

Societal opportunities involve possible changes in public policy or action by private organizations in an attempt to improve particular conditions in society at large. The creation of a new charitable organization or the invention or modification of governmental social programs are designed to take advantage of societal opportunities. One of the pitfalls of societal or governmental opportunities is

that it is difficult to know whether the imagined change can be realized by the proposed program or not; in business, at the very least, the sustained purchase of a profitable product or service by some set of consumers is a signal that someone, somewhere values the offering. Despite these difficulties of evaluating societal opportunity, the methods discussed here may be used in assessing such opportunities, but they are beyond the scope of our specific discussion.

Hereafter, we limit our discussion to commercial and entrepreneurial opportunities, their assessment, and how to proceed on the most promising of them.

Modality of Effect Opportunities differ in their primary mode or means of implementation:

- Technological invention
- Organizational modification
- Financial engineering
- Creative marketing

Some opportunities are enabled through changes in technology or the discovery of new science. Others come about through organizational modification. Increasingly, opportunities arise through more efficient deployment of capital through the mathematics and methods of finance. Still others come about through improved communications or marketing. Many of the opportunities of concern to entrepreneurial engineers are primarily technological or scientific in nature, but oftentimes, opportunities in the real world involve a combination of these factors. We shall focus on opportunities that have a significant technological component.

Locus of Opportunity in the Value Chain Commercial and entrepreneurial opportunities can be delineated by the primary locus of opportunity in the *value chain*. The term value chain has been used in the business strategy literature to distinguish common elements in a company's process flow. For example, Porter (1985) discusses primary value chain activities as follows:

1. Inbound logistics
2. Operations
3. Outbound logistics
4. Marketing and sales
5. Services

According to Porter, secondary activities include infrastructure, procurement, human resources, and technological development. Of course, entrepreneurial engineers may view technological development as more critical to the creation of a technological product or service than Porter, and, to be fair, Porter's analysis refers largely to going concerns with existing products and services. Nonetheless, it is useful to think of the enterprise systemically when seeking or trying to analyze different opportunities.

11.3 SUSTAINABLE COMPETITIVE ADVANTAGE: THE MAKING OF A GOOD OPPORTUNITY

In a competitive marketplace, enterprising individuals and companies are always on the lookout for new opportunities, and sometimes a new or existing company can get a head start on the competition. If the venturesome company is successful and the opportunity pans out, others will be attracted to it, however, and the advantage conferred by the head start can be quickly eroded by new competition or through the actions of important suppliers or customers. Knowing this, the entrepreneurial engineer will seek those opportunities that offer a *sustainable competitive advantage*, through the existence of one or more features of the product, service, or enterprise that are (a) different from those of competitive products and service and desired by customers, (b) difficult for the competition to emulate, and (c) difficult for suppliers or buyers to thwart. Here we divide our discussion into the four P's of competitive advantage and the five forces of sustainability.

11.3.1 Four P's of Competitive Advantage

The heart of competitive advantage is to *differentiate* a business from its competitors in a manner that is desirable or perceived to be valuable to its customers. To do this, introductory marketing texts talk about the big four control variables of marketing or the four P's:

- Product
- Place
- Price
- Promotion

Each of these is briefly reviewed.

In technology opportunity assessment, product is the king P of the four P's. Technology is used as a weapon to differentiate your product from other offerings, and it can be critical to have distinguishing features that customers will pay for.

The term *place* refers to where the business will be located, or more generally, what channels will be employed to get the product or service to customers. Companies selling software to the financial sector will do well to locate in New York, London, and other major financial capitals to be close to companies in their market. Companies that depend on recruiting specialized scientific and engineering talent will do well to locate near universities with excellent reputations in the needed talents. Of course, the virtual world of the Web has reduced somewhat the competitive advantage of physical presence or place. The Web permits customers almost anywhere to communicate, buy, and be serviced after the sale by companies that use e-mail, Web browsers, and other tools of online communication.

Price can distinguish a product from its competition, but startups should not usually aim at being the low-cost provider. Refining enterprise processes to make

complex technological goods more cheaply than the big boys is capital and time intensive; neither of these variables favors a small business. If anything, startups and small businesses should aim to get a premium price for products or services perceived as “well worth it.” High margins can cover a host of startup sins, whereas low margins can slow growth, delay breakeven, or worse.

Promotion or how a company penetrates a market with advertising, a sales force, manufacturers’ representatives, or other means can be another way of creating competitive advantage. Engineers often fall victim to the *better mousetrap* theory of invention that says that customers will beat a path to your door if you simply invent a better gizmo. Engineers are surprised when they don’t (and they usually don’t), and selling your product or service must be taken seriously. Of course, no one is suggesting that heavy promotion will ensure a lousy product’s success; however, a creative approach to promotion and market penetration can amplify important product differences and improve the perceived need for a product that might not otherwise exist.

Exploration Exercise

Consider a publicly traded company with products you are familiar with. In a short essay analyze the ways in which that company’s combination of product–place–price–promotion gives it a competitive advantage over its competitors. Of the elements you discuss, identify which factor you believe to be the most important and why.

11.3.2 Five Forces of Sustainability

At a systems level, Porter discusses the *five forces* that make an industry or business opportunity more or less *sustainable* (Porter, 1980).

1. Rival of industry competitors
2. Threat of new entrants
3. Threat of substitute products or services
4. Bargaining power of suppliers
5. Bargaining power of buyers

A sustainable opportunity is one where each of these five forces or threats is diminished by the very nature of the industry.

The existence of a large number of intense competitors going toe to toe in an opportunity area is not good news. Even if those competitors have not recognized the particular opportunity, as soon as they get wind of competitive activity, they will seek ways to get into the same or similar business. If they are savvy competitors, they may already be working on something along the same lines.

If it is easy to enter a business, this does not bode well for sustained profitability. Even if there are no competitors now, ease of entry will increase the probability that others will match or exceed a product or service quickly. For startups, it is commonly important to have some intellectual property (IP) that protects the ideas at the core of the business. The IP can take the form of patents, copyrights, trademarks, or trade secrets, but having some core IP and protection for that IP is crucial. If a company relies on trade secret protection, the product or service (a) must not be easily reverse engineered and (b) employees, suppliers, and others with access to trade secret information must sign and be held to nondisclosure agreements. Larger companies often rely on government regulation, their size, large capital requirements, and economies of scale to discourage new entrants, but these barriers to entry are not usually available to the startup or small-business entrepreneur.

Products and services with many possible substitutes are not a good bet. Although substitutes may not directly compete in the same marketplace, their existence may severely limit what a company can charge for a product, thereby reducing profit margins, lengthening payback, and otherwise making the investment less attractive.

Businesses where suppliers or buyers have a lot of clout should be avoided. If, for example, a company depends on a single customer for most of its sales, that buyer may suddenly threaten to drop the product unless the company cuts its price substantially. The best businesses are those with large numbers of uncoordinated buyers and suppliers, leaving a company in a position to play suppliers off each other and receive good prices from its customers.

The foregoing discussion is most useful for those technology opportunities that involve starting a new product line or a new company; however, understanding how different internal opportunities affect a company's competitive position can also be helpful in selecting among competing projects vying for limited internal investment.

Exploration Exercise

Consider the industry of the publicly traded company you selected in the previous exploration exercise. Analyze whether the industry is favorable with respect to sustainability using Porter's five forces, and present your findings in a short essay.

11.4 WHAT IS YOUR NICHE?

The term *niche* is used in ecology and informally it denotes a species' "place" in the world. More formally, an ecological niche is sometimes defined as a region of a multidimensional space of environmental factors that affect the well-being of an organism. In commerce, businesses have niches, too, and by analogy a company's niche may be defined as a region in a space of competitive or

environmental factors that affect the sustainable profitability of the business. In biology, physical location or geography plays an important role in determining an organism's niche, and likewise in business, where a business is located and where it distributes its products or services may be part of the niche, but as in biology, many other factors may go into the determination of a company's niche.

In biology, a principle called the niche exclusion principle is of particular interest here. The principle may be stated as follows:

Niche exclusion principle *In a competition between species that seek to exploit the same niche, only one species survives.*

This is quite stark, and when transferred to the business context, it highlights the importance of finding a niche. If a company goes after the same set of resources in the same neighborhood as a stronger competitor, given enough time, the company is likely to lose out.

Companies, like species, like to have large, resource-full niches all to themselves. By paying attention to the five factors and by considering the key elements to their profitability, companies carve out high profit margins and keep the amount of head-to-head coverage down to a manageable amount. Even companies in the same business do this. For example, in the automotive business, after the onslaught of Japanese competition in the family compact cars and sedan market, American manufacturers took refuge in the production of minivans, SUVs, and light trucks. Of course, American manufacturers did not give up on compact cars and sedans, but when large, powerful, longstanding companies struggle to carve out and profit from specialized niches in a market, the startup or smaller firm, with fewer resources and almost no economies of scale, must be clear about its niche and be convinced of its sustainability for some reasonable period of time.

A useful tool to help analyze an opportunity's niche is the so-called *positioning diagram*. Positioning diagrams (sometimes called *perceptual maps*) plot the imagined or measured location of a product or service on two or more attribute axes. For example, we might imagine the battle between automakers being played on competitive dimensions of price and function as shown in Figure 11.1. At the top of the price range are luxury vehicles and at the low-end are affordable cars. On the left end of the lifestyle dimension are conservative transportation automobiles, and on the right end are sporty vehicles. When consumers are asked to rate their perceptions of different automobiles, they locate them in different parts of the price–lifestyle space. High-performance German brands such as BMW and Porsche tend to be placed high on the price (luxury) scale, and they tend to be rated as high performance. American sedans such as Dodge and Ford, tend to be rated as lower priced and more conservative.

In trying to understand the competitive position of a new product or service, it is often difficult to obtain real data, but if the product or service is going into an existing market, positioning studies may be available with data regarding existing competition. Moreover, using such drawings as conceptual tools to understand whether an opportunity has a defensible niche is a common and useful exercise.

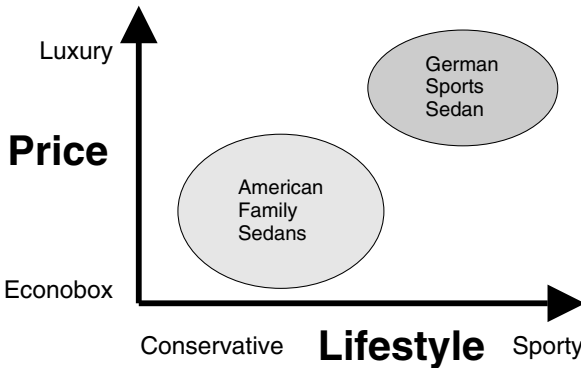


Figure 11.1 Positioning diagram or perceptual map helps visualize a product's niche.

Exploration Exercise

Consider a publicly traded company with a product you are familiar with. Choose two key factors that effect consumer choice with respect to this product. Sketch a positioning diagram, locating the selected company's product with respect to its competitors.

11.5 THREE FINANCIAL MYSTERIES OF OPPORTUNITY ASSESSMENT

In earlier times, when engineers were employed strictly on technical matters, their lack of understanding of key tools of financial communication and analysis was not important. With the rise of the entrepreneurial engineer, it is increasingly important for engineers to read financial statements, think relentlessly in terms of costs, prices, value, and breakeven, and to better understand the time value of money. Here we seek a short introduction to these items, although deeper coverage should be sought in an up-to-date text on engineering economics or managerial accounting (Park, 2002).

11.5.1 Overcoming the Fear of Financials

Engineers who have not seen them before can find financial statements quite daunting. At first, this “fear of financials” seemed odd because the mathematics employed in preparing financial statements rarely goes beyond basic arithmetic. However, over time, I’ve come to realize that the fear is born of a lack of understanding of key financial terms and principles underlying the statements. Although a complete introduction to financial statements is beyond the scope of our treatment, we concentrate on the following four items:

1. Cash flow statements
2. Balance statements

3. Profit-and-loss (income) statements
4. Ratio analysis

Each is briefly discussed below, but readers desiring a compact, yet thorough introduction to the topics should refer to Tracy's useful book (Tracy, 1999).

Cash Flow Is King

Ultimately, a new company wants to make profits, but cash is the mother's milk of starting a new business and is initially more important than profits. Even after a company becomes more established, if its cash position is neglected, it is difficult to meet payrolls, pay suppliers, and otherwise keep the business afloat despite theoretical calculations predicting a year-end profit.

Cash flow statements are the easiest of the three main financial statements to understand because they are *just like a checkbook*. The amount of money coming in, less the amount of money going out, equals the net increase or decrease in cash from all sources.

In reading financial statements, there is a convention that is almost universally used. Conventionally, engineers express positive quantities with a plus (+) sign or no sign at all and negative quantities with a minus (−) sign. Accountants express positive quantities with no sign at all and negative quantities inside of a pair of parentheses. Thus, using the accounting convention, \$100,000.00 and (\$100,000.00) are positive and negative one hundred thousand dollars, respectively.

Profit and Loss: Income Statements

Checkbook thinking is fine for running a household or for running a small proprietorship, but calculating profits for a large business on a checkbook or a *cash basis* can be severely misleading because, by their nature, incoming cash flows tend to be slow in arriving and outgoing cash flows are delayed as long as possible past the time of purchase. Moreover, large expensive investments in machinery and other capital equipment have a long useful life, and it is desirable to charge those expenses over multiple years. Therefore, most businesses larger than a mom-and-pop store calculate their profits on an *accrual basis*. That is, sales and normal expenses are recorded as soon as they are booked regardless when they are paid. Capital investments are *depreciated* over time, and a depreciation charge is taken each year to spread the cost of the expensive equipment over its useful life.

Keeping Your Financial Balance: The Balance Statement

Cash flow and income statements identify the *flow* of funds through a business in somewhat different ways. The balance statement is a *snapshot* of the *distribution* of assets, liabilities, and ownership (net worth or equity) at a given point in time.

These three things are related through the *accounting equation*:

$$\text{Assets} = \text{Liabilities} + \text{Owners' equity}$$

Assets are items of value possessed by the company or commitments by others to pay the company some amount. This latter quantity is called an *account receivable* because it is an amount that the company expects to receive in the future under current obligations.

Liabilities are current or long-term commitments to pay off loans, notes, or bonds in the future or current promises to pay others for goods or services ordered on account. This latter type of quantity is called an *account payable* because it is an amount that the company expects to pay as bills come due in the future.

The difference between assets and liabilities is then the owners' equity or the financial net worth of the company.

Ratio Analysis: Dimensional Analysis with Money

Engineers commonly use *dimensionless ratios* such as the Reynolds number and the lift coefficient to help understand complex experimental data, organize equations and model building, and relate model testing in a wind tunnel to that of a prototype flight. This kind of analysis is called *dimensional analysis* because it uses the dimensional nature of important variables to derive dimensionless parameters that determine the scaling properties of a physical system.

In financial matters, a similar technique, *ratio analysis*, is used to judge whether a company is healthy with respect to industry standards. In ratio analysis most of the quantities compared are quantities of money, so the ratio of one quantity of money to another quantity of money is, by definition, a new dimensionless ratio (like the Reynolds number or lift coefficient), and these financial ratios can be used to compare businesses in similar industries or businesses (in engineering, such comparison is referred to as *dynamic similitude*).

Perhaps the most familiar ratio to the ordinary investor is the so-called price-to-earnings (P/E) ratio:

$$\text{P/E ratio} = \frac{\text{Current market price}}{\text{Earnings per share}}$$

P/E values are used to judge whether a stock is a good value relative to its earnings stream. Another way to think of the P/E is to take its reciprocal and think of that number as an interest rate. This interest rate interpretation would be completely valid if the entire amount of the company earnings per share were paid out as a cash dividend. For example, a P/E of 20 can be thought of as comparable to an interest rate of $1/20 = 5\%$.

Various ratios measure profits relative to investment and sales. Two important ones are *return on sales* (ROS) and *return on equity* (ROE):

$$\text{ROS} = \frac{\text{Net income}}{\text{Sales revenue}}$$

$$\text{ROE} = \frac{\text{Net income}}{\text{Shareholder's equity}}$$

Other ratios measure creditworthiness. One such measure is the debt-to-equity ratio:

$$\text{Debt-to-equity ratio} = \frac{\text{Total liabilities}}{\text{Total stockholder's equity}}$$

Generally, lenders like to loan money to those who have more to lose in bankruptcy than they do, and debt-to-equity ratios less than 1 ensure this.

Exploration Exercise

Consider a publicly traded company with products you are familiar with. Obtain a copy of the company's annual report. Examine and interpret the cash flow, income, and balance statements. Is the company profitable? Did the company's cash position improve or degrade last year? Did stockholder equity improve or degrade last year? Calculate the ratios discussed in this section. Using library data or data off the Web, compare the companies averages to industry averages. In what ratios is the company's position favorable or not.

11.5.2 Prices, Margins, and Breaking Even

Financial analysis of new technology can get fairly sophisticated, and detailed business plans can contain a variety of means of projecting revenues, but the most useful starting point for thinking about the finances of a technology opportunity is simple breakeven analysis.

Simple breakeven analysis turns on building a simple linear model relating various costs and price. Say we get a price P per unit of product for which we pay a fixed cost F and a variable cost V . If we sell n units of the product, we may calculate the net revenue R received as follows:

$$R = nM - F \quad (11.1)$$

where the contribution margin is defined as the difference between the unit price and the variable cost $M = P - V$.

Breakeven occurs at that volume n_b where net revenue $R = 0$. This results in a relationship between breakeven volume, fixed cost, and contribution margin as follows:

$$F = Mn_b \quad (11.2)$$

or solving for n_b ,

$$n_b = F/M \quad (11.3)$$

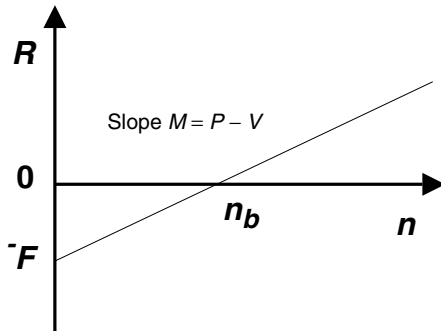


Figure 11.2 Breakeven analysis is illustrated by a plot of revenue versus volume. At zero volume, the fixed costs are fully charged. At breakeven, net revenue is zero, and above breakeven, the margin accumulates straight to the bottom line.

Finally, total revenue may be written in terms of M and the breakeven point by substituting Equation (11.2) into (11.1):

$$R = (n - n_b)M \quad (11.4)$$

In words, the net revenue can be calculated as the excess volume over breakeven times the unit contribution margin.

In all these calculations, the key quantity is, not so much the price or the variable cost itself, but rather their difference, the contribution margins. All efforts to widen margins result in a concomitant reduction in breakeven point and increase in net revenue.

Graphically, the situation is illustrated in Figure 11.2, where net revenue is plotted as a function of volume. Of course, the mathematics here is nothing fancy, but the beauty of breakeven analysis is in the distinction it makes between fixed costs and variable ones. By making that distinction, you can calculate roughly and quickly to better assess opportunities as they arise.

11.5.3 Time Value of Money

Simple breakeven analysis is quite useful for getting a ballpark sense of when a given investment will start to payoff, but more sophisticated analysis will take account of the alternative uses of money and the fact that a dollar today is worth more than a dollar tomorrow.

The key idea is to take a present amount P and account for the interest i that will compound over n periods to give some future amount F as follows:

$$F = P(1 + i)^n \quad (11.5)$$

The validity of the equation is easy to verify as in one period the amount P will be increased by the multiple $1 + i$. In the next period it is increased by an identical factor and so on for n periods.

Almost all sophisticated financial analyses of opportunities or various deals start from this point of departure. Getting used to “moving” sums of money around in time through the use of Equation (11.5) will help you better understand this kind of analysis.

11.6 WRITING THE TECHNOLOGY OPPORTUNITY ASSESSMENT

In assessing technology opportunities, it is important to understand what the opportunity is, whether it represents a sustainable competitive advantage, the market for the opportunity, a preliminary financial analysis, and a discussion of personnel who are key to exploiting the opportunity.

The elements of a TOA are fivefold:

1. Executive summary
2. Opportunity description
3. Preliminary market analysis
4. Preliminary financial analysis
5. Action plan

Each of these can be further discussed.

11.6.1 Executive Summary

The executive summary is a one- or two-page summary of the main points in the body of the TOA. A good format is to use *titled paragraphs or sections*, where a sequence of paragraphs or sections are headed by a headline in a bold font.

Good executive summaries are hard to write because they need to be brief yet contain the key ideas in a form that is easily and quickly grasped. A good process to follow is to write the individual sections of the opportunity assessment first, and then work on condensing the larger sections down to their essentials.

A key to this condensation step is to think primarily in terms of what the decision maker or investor needs to know to make a decision in your favor. Thinking in these terms usually (a) eliminates technical detail unrelated to competitive advantage, (b) boils financials down to aggregate numbers and key profitably statistics such as time to breakeven and return on investment, and (c) increases the use of familiar products and companies as analogies.

This condensation step should be taken a step further in the preparation of an *elevator pitch*. Imagine you are riding in an elevator with a famous venture capitalist (VC). You have one minute to interest this person in your idea before the elevator door opens. What would you say? Probably you need to tell the VC the following:

- Company/product name and location
- The fundamental market problem the company solves

- How the company/product overcomes the problem
- The sustainable competitive advantage the company has over other approaches

In other words, the elevator pitch takes your executive summary and condenses it down to a single short paragraph. If you thought the condensation from full business plan or opportunity assessment or executive summary was hard, the condensation down to an effective elevator pitch can be excruciating, but it is necessary. Busy people don't have long periods of time to assess whether what you are doing is interesting or not. They decide quickly, and their default decision is "no." Learning the art of the executive summary and elevator pitch are important to getting your ideas accepted by busy decision makers and investors.

Exploration Exercise

Consider a technology opportunity that might lead to a new business. Do a preliminary Web search to see if there are companies doing something similar. Write an elevator pitch for the idea as a prelude to preparing a full TOA.

11.6.2 Technology Description

A key element of any technology opportunity assessment is the description of the technology. In doing so you need to cover the following elements:

1. The type of opportunity
2. The purpose and function of the technology
3. The current stage of development of the technology and additional work required to commercialization
4. Barriers to imitation
5. Regulatory and legal concerns
6. Implementation or production of technology

Each of these is briefly considered.

Type of Opportunity By "type" of opportunity, the reader of the TOA wants to know whether the opportunity is

- Internal
- External
- Startup

An internal opportunity is one where internal processes or procedures in an existing organization are modified to realize some reduced cost, improved quality,

or some other benefit. An external opportunity is where an existing corporation modifies an existing product or service or starts a new product or service. A startup opportunity is where a new business entity is created to launch a new product or service.

Purpose and Function of the Technology In this section, describe what the technology is supposed to do for the user or customer and give a concise yet qualitatively complete description of how the technology works.

Current Stage of Development and Work Required to Commercialization Is the idea merely a concept, or has pilot or prototype development occurred, and how far along is that development? What further effort is required to create a version that may be used or sold?

Barriers to Imitation How is the idea protected from imitation by competitors? Is it protected by intellectual property law through patent, copyright, or trademark? If not, is it difficult to imitate by its nature? How so? Is it difficult to reverse engineer? Is it protected as a trade secret? Are there unique, exclusive sources of components or other supplies? Are unique labor inputs required to develop, maintain, support, and extend the product or service?

Regulatory and Legal Concerns Does the technology fall under a governmental regulatory regime? In what ways? What government licenses or permission must be obtained before the product can be manufactured and sold? What potential uses or misuses of the product or service will open the company to product liability or other lawsuits?

Implementation or Production of the Technology How will the technology be implemented or manufactured? Will an in-house capability be developed or will manufacture be outsourced?

Exploration Exercise

Consider a technology opportunity that might lead to a new business. Write an opportunity description for the idea.

11.6.3 Market Analysis

Describing your gizmo is the easiest part of the technology opportunity assessment exercise, but now the going gets tougher. A critical part of the analysis is to assess whether there is a market for what you want to do. For an internal opportunity, your “market” is some “customer” within your own organization, and a

formal market analysis may be unnecessary. For a commercial or startup opportunity, however, it is essential to do a good job in collecting facts and figures about your market, and then presenting that data to show there is a sufficient market to exploit your opportunity.

Incomplete List of Sources for Market Data

There are many sources of market analysis data:

- Trade magazines, associations, and websites
- Publicly traded company data and corporate websites
- Government and private statistical sources
- Privately prepared market research reports

Established industries almost always are served by a trade press and many have formal trade associations, some with websites and magazines. Consumer markets are often driven by demographics and *American Demographics* (www.demographics.com) is a useful reference. If your competitors are publicly traded, their Securities and Exchange Commission (SEC) filings have useful data (www.10kwizard.com), and many companies have useful information on their websites. The U.S. government has a wealth of statistical data, and most of the useful sites can be reached from the website www.fedstats.gov. Dun and Bradstreet (www.dnb.com) and Hoovers (www.hoovers.com) are useful sources of corporate information, although useful data comes at a price. There are a number of firms that provide market research reports on different segments of various markets for a price and Web searches should reveal some of the best known quite quickly. Business media outlets (www.bloomberg.com and www.wsj.com) are useful sources of information as well.

Writing the Market Analysis

Collecting market data for the first time can be an enlightening experience for entrepreneurial engineers, but organizing that data into a coherent market analysis is a challenging task. To make that task easier, we outline a number of elements of the analysis in a sequence that will lead to a sophisticated analysis. In particular, we suggest working from the bottom up, starting from the product to the individual customer to the market segments that might benefit from your product:

- Analysis of features, benefits, and consequences (FBC)
- Analysis of customers
- Analysis of competition
- Most promising market segments, size, and gradient
- Market penetration and promotion

Each of these is briefly discussed.

FBC Analysis

Although the first section of the TOA analyzes the opportunity in technological terms, the market analysis must revisit the product or service through the *eyes of the customer*. In particular, the analysis of features, benefits, and consequences considers what the product or service does and how that benefits the customer directly and in the long term. An example from a common software product will make this clear.

Consider a word processing program. A common useful *feature* is the built-in spelling checker. How do spell-checks *benefit* a customer? They reduce the number of misspelled words in a document, and they reduce the need to consult a dictionary as often when you are uncertain about the spelling of a word. Longer term, what are the consequences of these benefits? Documents with good spelling may improve business for the user because bad spelling is viewed as a sign of carelessness. The time savings of not having to consult a dictionary as frequently will make a user more productive, and the time savings can be used to spend more time with loved ones, a hobby, or to get more work done.

By thinking deeply about the features of a product as well as their benefits and consequences for customers, you build the foundation for your entire marketing plan.

Customer Analysis

Having thought about how the product affects customers through FBC analysis, it is time to consider the customers themselves. In particular, we decompose the customer analysis along three dimensions:

1. Demographics
2. Role analysis
3. Decision paths

Each of these is considered briefly.

Demographic analysis considers the age, cultural, and gender distribution of the customer. In consumer products, demographic analysis is crucially important, but even in more technical goods and services, knowing the demographic distribution of your target market can be helpful in product design and the design of market penetration campaigns.

Role analysis examines the type of role being played by your customers, and we can distinguish between *titular* and *purposive* roles. Titular roles are those associated with the usual *titles* people possess in the job market. For example, is the customer a CEO, an engineer, a clerk, or a factory worker? Knowing your customer along these lines tells you a lot about their educational background, level of technical expertise, and what's important to them in making a buying decision.

Analyzing a customer's purposive role tells us the broader purpose behind his or her buying decision, and we can distinguish between three broad categories: utility, instrumental, and display. Ordinary consumers of goods and services seek

utility directly. For example, a buyer of a Krispy Kreme doughnut buys a fat-filled confection and benefits (so he or she believes) from the sensory stimulation (and immediate weight gain) of consumption.

For many technical goods and services, the customer buys the product as an *instrument of success* in some other enterprise. If you make components that others can use, customers buy those components to add value to their larger system. Finally display customers buy things, at least in part, to show them off to others. Luxury consumer goods fall into this category, and the status conferred by displaying symbolic trademarks can be as important as the functionality of the product. Technical goods and services usually require utility or instrumentality, but it can be beneficial to pricing and margins if technical goods and services customers are motivated at least partially on display grounds.

A crucial element to marketing is understanding the various paths of buying decisions. Complex technical goods often are *recommended* to upper management by low-level engineers or technicians. Depending on the organization and the cost of the goods, the actual decision might require a whole host of signatures up the chain of command. In selling goods and services, it is important to have access to the ultimate decision maker, but it is equally important to understand the chain of recommenders that leads to that person's desk.

Competition Analysis

Creating and maintaining a sustainable competitive advantage requires that you fully understand the direct and indirect competition for your technology opportunity. What firms and products and services compete with your technology? What market segments do these firms supply? What share of those market segments do these companies currently occupy? How do competitor products and services stack up on FBC terms with your proposed offering. How do your customers price their product? Along what dimensions is your offering unique and can that uniqueness be represented with a positioning diagram or perception map?

Most Promising Markets and Segments

Given your product/service offering, your customer, and your services, what are the most promising markets or market segments for you to target? How large are they and how fast are they growing?

Market Penetration and Promotion Analysis

Given you offering, your customers, and markets, what are the most effective means of reaching your target audience?

- Dedicated sales force
- Manufacturers representatives
- Direct mail
- E-commerce

- Telemarketing
- Piggyback sales (bundling your product into another)

These categories discuss the means by which you *actively* mean to close sales, take orders, and deliver product.

Additionally, there a number of ways that you intend to *inform* potential customers of your offerings as preparation to closing sales. Specifically, what means of advertising and publicity will reach your target customers most effectively?

- Trade advertising
- Mass media advertising
- Trade shows
- Catalogs
- Web-based promotion
- Press releases

In a short time, Web-based approaches have become a great equalizer in marketing and promotion. Although other traditional methods of reaching customers must be exploited, it is the rare new business today that does not use the Web to some degree in penetration and promotion efforts.

Exploration Exercise

Consider a technology opportunity that might lead to a new business. Investigate and write a preliminary marketing analysis for the idea.

11.6.4 Preliminary Financial Analysis

In writing a preliminary financial analysis, the main point is to determine whether the business has sufficient margins and volume to justify a business. This can range from a simple back-of-the-envelope breakeven analysis to a more complete set of 3-year pro forma. More formal texts on entrepreneurship (Timmons, 1999), business planning short courses and workbooks (www.fastrac.org), and business planning software (www.bplan.com) can be used on the more formal end of this planning spectrum.

At a minimum, you need to estimate the financial picture surrounding your budding opportunity. A 3-year time frame is a good starting point, and income and outflow should be estimated in the following categories:

- Product sales volume and pricing
- Research and development expenses
- Marketing, promotional, and sales expenses
- Administrative expenses

The art of estimating volume and pricing for a new product is quite difficult. Knowledge of competing or similar products can be quite helpful in projecting reasonable prices, initial volumes, and reasonable growth rates. Most investors will not take wild guesses at face value, so use of historical data in an existing market or analogous market is almost essential.

Research and development expenses include R&D (research and development) salaries, licensing fees (for technology owned by others), patent filings, equipment leasing, and other expenses surrounding the protection of intellectual property. Salaries, legal fees, and other expenses can be estimated fairly accurately; the difficulty in giving accurate estimates of R&D expense estimates are usually tied to the uncertainty inherent in estimating the amount of time and effort required to get to a marketable product. A technology coming from a university or other laboratory often requires a fair amount of development to make it suitable for use in a product. The engineer's natural tendency to tinker and to raise the specifications bar as more is learned exacerbate this problem.

Exploration Exercise

Consider a technology opportunity that might lead to a new business. Investigate and write a preliminary financial analysis for the idea.

11.6.5 Action Plan

To this point, the technology opportunity assessment has been an exercise in exactly that, assessment. The final section of the TOA discusses the most promising options going forward, and it should contain the following information:

- Discussion of most promising options
- Projection of financing required and potential sources
- Analysis of key roles and personnel

Each of these is briefly considered in what follows.

Selection of Most Promising Options

The purpose of the TOA is to help you to decide what to do with the technology opportunity at hand. Here you make a list of one or several options that appear to be most promising and evaluate your current assessment of likely success for those options. Typical options include the following:

- Move ahead with technology opportunity.
- Write a full business plan.
- Seek licensing opportunities for the technology.

- Seek additional input on the feasibility of the idea.
- Continue development of technology outside commercial arena.
- Shelve the technology or discontinue continued evaluation.

Each of these is discussed.

The most aggressive move is to move ahead with the technology by starting a new company or starting a new business within an existing company. Normally, TOA information is insufficiently detailed for this purpose; however, a particularly well-researched TOA or a particularly hot idea may warrant moving ahead without the formality of a full business plan.

The usual way to proceed with a promising TOA is to write a full business plan as a preparatory step to doing the startup. Normally, TOAs do not contain sufficient market, financial, executive team, corporate structure, or corporate operational detail to launch a new business, and writing a formal business plan starts from the TOA and adds the necessary detail.

The TOA process may reveal commercial possibilities that the assessment team is not interested in pursuing themselves. In cases such as this, it may make sense to explore the possibility of licensing the technology to others. The TOA has probably identified key players in existing and related markets, and that list may be a good list of licensing prospects.

Despite thorough research, technology opportunity assessment may come back with an inconclusive assessment. In those cases, the technology may not quite be ripe or the markets may not yet be sufficiently developed. In cases such as this, it may be useful to shop the TOA around to potential investors, academics, and potential customers, not with the idea of getting an investment, but with the objective of getting feedback on how to reshape the idea so that it is more obviously promising.

Occasionally, a TOA will reveal ways in which the technology must be improved before it is marketable. This suggests returning to the lab to improve the technology along those lines; however, engineers, even entrepreneurial ones, have a predisposition toward playing around with and fine tuning their gizmos. If your assessment suggests going back to the lab, make sure the reasons are sound. An imperfect technology with a strong competitive advantage today is far superior to a perfected technology entered into an already established marketplace.

Finally, one usually undertakes a TOA with the idea of moving ahead somehow, but data is data, and the assessment may reveal any number of deal breakers:

- Extant technology in the market with comparable features
- Insufficiently large market to build a profitable business
- A technology with competitive advantage that is not sustainable

Each of these argues against going ahead with the opportunity, but the determination of viability along these dimensions is subtle.

The existence of competitors does not automatically preclude moving ahead. Perhaps the competitors have been lazy or have not kept up with advances in technology. You seek competitive advantage, not necessarily monopoly.

Many venture capitalists like to see a billion-dollar market before backing a technology idea, and perhaps your TOA doesn't add up to something that sizable. Perhaps you have undervalued the potential for growth of the market, or perhaps you have ignored market segments that could add up to sufficient size.

Technology with a current competitive advantage that enters a ruthless market of rampant rivalry, ease of entry, power exerted by suppliers and buyers, and many substitutes is in some ways asking for future trouble. The technology may have a temporary competitive advantage initially, but market conditions may cause a variety of pressures that erode that advantage. Even in these daunting circumstances, going ahead may be possible if you can imagine a way to stay ahead of the pack. Technology, by its very nature, is a dated product. Anyone entering a technology-based business is either implicitly or explicitly signing up to live a life of continual improvement and innovation. Perhaps one approach to such a competitively relentless pursuit is to think like a chess player. Plan out your opening, but also think through your strategy and tactics for the middle game as well. If you can imagine a sequence of innovations that will keep you ahead of the competition, your chances for longer term survival will improve.

Analysis of Key Roles and Personnel

Technology inventors are a proud bunch, and it is often the case that the key technologists are important players in getting the technology opportunity off the ground. It is possible for inventors, however, to overestimate their importance in the larger scheme of things, and there are many other key players in a technology startup.

- Chief executive officer
- Chief financial officer
- Chief technical officer
- Sales manager

The technology inventor will, for example, often be tempted to take on duties as CEO along with technology development responsibility, but this can be a mistake unless the inventor has significant prior business experience. A CEO with a track record of entrepreneurial success and a current Rolodex full of friends in strategic places can organize routine business functions, access funding, make initial product placements, and do other important tasks more quickly and better than a novice company president doing expensive on-the-job training.

The chief financial officer (CFO) keeps tabs on where the money is coming from and going. Despite continuing financial shenanigans by CFOs at a number of high-profile companies, the traditional role of a CFO is to be a company's chief reality therapist. Good and bad news is best reflected in the financial statements, and a good CFO keeps the growth plans and expectations in line with market reality.

The chief technical officer (CTO) is responsible for technical research and development. This is a position that many inventors will assume in startups, but

taking the title of CTO requires a level of managerial responsibility that the lone inventor is not ready for. Many technically based companies will assign the founding inventor a position as technological guru or thinker-in-chief that requires a maximum of inventiveness and a minimum of line managerial responsibility.

Sales are the lifeblood of all commercial enterprises, and the care and feeding of a sales force, and the selection of a sales manager, can be a mystery, pure and simple, to the average engineers. By the nature of the business, salespeople are extraverted, intuitive, and brash, and this can be a clash of cultures with introverted, rational, and conservative engineering personalities. Understanding these personality and cultural differences is important.

Exploration Exercise

Consider a technology opportunity that might lead to a new business. Write an action plan for the idea.

Projection of Financing Required and Identification of Potential Sources

Many of the most promising options will require significant levels of funding to proceed. The preliminary financial analysis will help estimate the cash needs to get started, but the entrepreneurial engineer's tendency toward optimism will, in this case, tend to underestimate cash needs.

Funding can be raised from a variety of sources (in rough order of increasing cost and increasing loss of control):

- Personal funds of the startup team
- Friends and relatives of the startup team
- Entrepreneurial incubators
- Angel investors
- Venture capitalists
- Initial public offerings
- Merger

The first four of these occur early in a company's development, and the latter three occur somewhat later.

The initial funding of a new technology business will often come from the inventors, their startup team, or personal friends and relatives. This is the iconic "garage" startup of Hewlett-Packard and Apple legend. More and more, entrepreneurs are being supported by incubators on university campuses or elsewhere with seed funding, low-cost office space, and experienced business advice. Beyond incubators is an important class of funding from so-called *angel* investors. Angels are wealthy, knowledgeable investors, often entrepreneurs themselves,

who have money to invest, often in businesses related to their own personal technical or business expertise. Angels generally are willing to invest smaller amounts earlier than so-called venture capitalists (VCs).

Venture capital firms are professional organizations that raise funds to invest in startups well beyond the incubation stage. Beyond these private sources of funds, companies can raise money by selling stock to public stock markets through *initial public offerings* (IPOs). Public offerings are not usually possible until a company has a track record of successful products and profits. Finally, there can come a point where a company believes its financing and market access is fundamentally limited by its size or market conditions. In such cases, the financing for growth can come from a larger company that acquires your firm. Oftentimes, the larger company exchanges shares of its stock, cash, or some combination of cash and stock to acquire the smaller firm.

Exploration Exercise

Consider a technology opportunity that might lead to a new business. Assemble a full technology opportunity assessment from previously written pieces. Write an appropriate executive summary, and prepare a 10-minute presentation on the idea for presentation to an group of potential investors. Make the presentation.

SUMMARY

The chapter started by considering the changing role of engineers within companies and organizations today. Where once engineers were largely responsible for demonstrating technical feasibility, they now are more intimately involved in the search for and exploitation of opportunity. These new responsibilities require that engineers understand their organizations from a systems point of view. Specifically, this systems viewpoint requires a more sophisticated approach to customers, markets, finances, and their interrelationship to the technology itself.

The chapter defined opportunity as a “correctable difference between the way things should be and the way things are,” and this definition highlights three things. Opportunities are about (1) change, for the (2) better, in a (3) realizable manner. The chapter categorized opportunities depending upon their sphere of influence, modality, and locus. Sphere of influence relates to *what* opportunities affect. Are they personal, entrepreneurial, commercial, or even societal? Modality refers to *how* an opportunity creates change. Is it done through technological, organizational, financial, or marketing means? Locus refers to *where* opportunity exists in a company’s value chain. Is the opportunity an improvement in supply or delivery of product? Is it a manufacturing innovation, a marketing innovation, or a services innovation?

A key concept in evaluating opportunity is the notion of sustainable competitive advantage. The competitive advantage side of this comes by differentiating the product or service delivered along the four P lines: product, place, price, or promotion. The sustainability of the competitive advantage is often examined through the lens of Porter’s five forces. Those opportunities with modest rivalry, low threat of new entrants, difficulty in substituting

other products or services, and poor bargaining power of suppliers and customers are most likely to be sustainable in the long run. Opportunities threatened along one or more of these dimensions are depending upon successfully outflanking their competitors, suppliers, and customers over the long haul.

The ecological notion of a niche was defined and carried over to the business context. In ecology, niches are sets of environmental factors that affect the well-being of an organism, and the same definition carries over to business if we simply substitute the term *business* for the term *organism*. The niche exclusion principle in biology suggests that in the long run, there will only be one survivor in a particular niche between two or more organisms. In business, this places a premium on some kind of differentiation of your product from your competitors. The chapter discussed the idea of a positioning diagram or perceptual map to help visualize niches graphically.

The chapter considered the engineer's "fear of financials" and attempted to overcome it with a straightforward discussion of cash flow, income, and balance statements. The mathematics of these statements is simple arithmetic, but the confusion seems to come from not understanding a few key terms. The chapter also considered the utility of ratio analysis—what engineers might call dimensional analysis for companies—breakeven analysis, and the basics of the time value of money. Although a full discussion was beyond the scope of this chapter, the discussion served up the basics and may also serve to introduce more careful treatments in other courses or texts.

The chapter concluded by outlining the preparation of a written technology opportunity assessment, or TOA. TOAs should have a clear executive summary, a description of the technology opportunity, preliminary marketing and financial analyses, and an action plan or recommendation. TOAs are difficult documents to write because they range broadly across a system as an enterprise yet focused on making a business case for investors or other decision makers TOAs can be the basis of direct action, a more detailed business plan, or they can lead to more development or shelving of the technology. From the standpoint of the entrepreneurial engineer, trying your hand at writing a technology opportunity assessment can be one of the quickest ways to become more familiar with the complex interplay between technology and the enterprise it enables and serves.

EXERCISES

1. Read the *Wall Street Journal* for one week, collecting one article each day that discusses technical opportunities that various companies are considering or exploiting. Try to choose articles from the same or a related industry. In each of the articles identify key points of competitive advantage for the particular opportunity and in a short essay discuss whether those advantages are likely to be sustainable using Porter's five forces analysis.
2. Select an article in the business press that discusses a company that is in financial difficulty or bankruptcy. Identify (a) how the company got into financial difficulty, (b) what steps it is taking to get out of financial difficulty, and (c) whether additional funds are being injected into the firm and by whom.
3. Many methods of using the Web for marketing were tried in the early days and some of them have survived. Identify five websites that use different approaches to using the Web to reach customers. Write a short synopsis of each approach and assess whether the same or similar approach can be used for promoting a technology-based opportunity.

4. Over the course of 2 months, “adopt” a publicly traded company by following its stock price, annual report, financial news, products, SEC 10 K filings, industry analyst reports, and other data. Is the firm relatively strong with respect to its industry? Why or why not? Were the reasons for relative success or failure apparent at the point of decision? In hindsight were there any steps the company could have taken that would have improved its current situation?
5. Repeat Exercise 4 using one of the company’s listed in Jim Collins’s (2001) book *Good to Great*. Use one of the good-to-great companies or the reference not-so-great companies.
6. Investigate a university near you for campus resources designed to aid entrepreneurs. Write a list of resources, services, funding sources, and other aid that the university can help you obtain.
7. Read the Web pages of three venture capital firms. What businesses have they invested in and at what stage? Compare and contrast the firms based on the information provided on the website.
8. A properly investigated technology opportunity assessment is a substantial undertaking, requiring library and Web data collection, analysis, creative problem solving, and thoughtful projections. Prior to investing that kind of time, it is sometimes helpful to do a prescreening on the basis of more cursory investigation. A useful pre-TOA analysis focuses on (a) the idea, (b) competition, and (c) a back-of-the-envelope breakeven analysis.
9. A common technique for inventors and other creative problem solvers is to create a *bug list* of nagging problems or difficulties in the world that might be deserving of a clever and profitable solution.
10. Attend a trade show in an area of commercial interest to you. Observe the array of companies present, product and service offerings, promotional activities, and the interaction of trade show vendors and customers. Write a short memo listing and analyzing your observations.
11. Obtain a business plan on the Web at www.bplan.com or comparable site. Write a critique of the style and substance of the business plan.
12. Make a list of websites helpful to technology opportunity assessment. Start with the Kauffmann foundation’s website www.entreworld.org.
13. Jim Collins, author of the bestseller *Good to Great*, has written that social or organizational innovation is often more important to business success than technical innovation. Write an essay debating the merits and shortcomings of this argument.