CHAPTER 8

Building the innovation case

The usual motive for developing a formal business plan is to secure support or funding for a project or venture. However, in practice business planning serves a much more important function, and can help to translate abstract or ambiguous goals into more explicit operational needs, and support subsequent decision making and identify trade-offs. A business plan can help to make more explicit the risks and opportunities, expose any unfounded optimism and self-delusion, and avoid subsequent arguments concerning responsibilities and rewards.

8.1 Developing the business plan

No standard business plan exists, but in many cases venture capitalists will provide a pro forma for their business plan. Typically a business plan should be relatively concise, say no more than 10–20 pages, begin with an executive summary, and include sections on the product, markets, technology, development, production, marketing, human resources, financial estimates with contingency plans, and the timetable and funding requirements. A typical formal business plan will include the following sections:[1]

1. Details of the product or service.
2. Assessment of the market opportunity.
3. Identification of target customers.
4. Barriers to entry and competitor analysis.
5. Experience, expertise and commitment of the management team.
6. Strategy for pricing, distribution and sales.
7. Identification and planning for key risks.
8. Cash-flow calculation, including breakeven points and sensitivity.
9. Financial and other resource requirements of the business.

Most business plans submitted to venture capitalists are strong on the technical considerations, often placing too much emphasis on the technology relative to other issues. As Roberts notes, ‘entrepreneurs propose that they can do *it* better than anyone else, but may forget to demonstrate that anyone wants *it*’.[2] He identifies a number of common problems with business plans submitted to venture capitalists: marketing plan, management team, technology plan and financial plan. The management team will be assessed against their commitment, experience and expertise, normally in that order. Unfortunately, many potential entrepreneurs place too much emphasis on their expertise, but have insufficient experience in the team, and fail to demonstrate the passion and commitment to the venture (Table 8.1).

TABLE 8.1 Criteria used by venture capitalists to assess proposals

Criteria	European (n = 195)	American (n = 100)	Asian (n = 53)
Entrepreneur able to evaluate and react to risk	3.6	3.3	3.5
Entrepreneur capable of sustained effort	3.6	3.6	3.7
Entrepreneur familiar with the market	3.5	3.6	3.6
Entrepreneur demonstrated leadership ability*	3.2	3.4	3.0
Entrepreneur has relevant track record*	3.0	3.2	2.9
Product prototype exists and functions*	3.0	2.4	2.9
Product demonstrated market acceptance*	2.9	2.5	2.8
Product proprietary or can be protected*	2.7	3.1	2.6
Product is 'high technology'*	1.5	2.3	1.4
Target market has high growth rate*	3.0	3.3	3.2
Venture will stimulate an existing market	2.4	2.4	2.5
Little threat of competition within 3 years	2.2	2.4	2.4
Venture will create a new market*	1.8	1.8	2.2
Financial return >10 times within 10 years*	2.9	3.4	2.9

(continued)

TABLE 8.1 (Continued)

Criteria	European (n = 195)	American (n = 100)	Asian (n = 53)
Investment is easily made liquid* (e.g. made public or acquired)	2.7	3.2	2.7
Financial return >10 times within 5 years*	2.1	2.3	2.1

1 = irrelevant, 2 = desirable, 3 = important, 4 = essential. * Denotes significant at the 0.05 level.
Source: Adapted from Knight, R. (1992) Criteria used by venture capitalists. In T. Khalil and B. Bayraktar, eds, *Management of Technology III: The Key to Global Competitiveness* (pp. 574–83), Industrial Engineering & Management Press, Georgia.

There are common serious inadequacies in all four of these areas, but the worst are in marketing and finance. Less than half of the plans examined provide a detailed marketing strategy, and just half include any sales plan. Three-quarters of the plans fail to identify or analyse any potential competitors. As a result most business plans contain only basic financial forecasts, and just 10% conduct any sensitivity analysis on the forecasts. The lack of attention to marketing and competitor analysis is particularly problematic as research indicates that both factors are associated with subsequent success.

For example, in the early stages many new ventures rely too much on a few major customers for sales, and are therefore very vulnerable commercially. As an extreme example, around half of technology ventures rely on a single customer for more than half of their first-year sales. An overdependence on a small number of customers has three major drawbacks:

1. Vulnerability to changes in the strategy and health of the dominant customer.
2. A loss of negotiating power, which may reduce profit margins.
3. Little incentive to develop marketing and sales functions, which may limit future growth.

The case of Plaswood Recycling provides a good example of how to assess a new business concept.

Therefore it is essential to develop a better understanding of the market, and technological inputs to a business plan. The financial estimates flow from these critical inputs relatively easily, although risk and uncertainty still need to be assessed. This chapter focuses only on the most important, but often poorly executed, aspects of business planning for innovations. We first discuss approaches to forecasting markets and technologies, and then identify how a better understanding of the adoption and diffusion of innovations can help us to develop more successful business plans. Finally, we look at how to assess the risks and resources required to finalize a plan. We will return to the development of business plans in Chapter 10, in the specific context of new venture creation.

RESEARCH NOTE What is the 'fuzzy front end', why is it important, and how can it be managed?

Technically, new product development (NPD) projects often fail at the end of a development process. The foundations for failure, however, often seem to be established at the very beginning of the NPD process, often referred to as the 'fuzzy front end'. Broadly speaking, the fuzzy front end is defined as the period between when an opportunity for a new product is first considered, and when the product idea is judged ready to enter 'formal' development. Hence, the fuzzy front end starts with a firm having an idea for a new product, and ends with the firm deciding to launch a formal development project or, alternatively, decides not to launch such a project.

In comparison with the subsequent development phase, knowledge on the fuzzy front end is severely limited. Hence, relatively little is known about the key activities that constitute the fuzzy front end, how these activities can be managed, which actors participate, as well as the time needed to complete this phase. Many firms also seem to have great difficulties managing the fuzzy front end in practice. In a sense this is not surprising: the fuzzy front end is a crossroads of complex information processing, tacit knowledge, conflicting organizational pressures, and considerable uncertainty and equivocality. In addition, this phase is also often ill-defined and characterized by ad hoc decision making in many firms. It is therefore important to identify success factors which allow firms to increase their proficiency in managing the fuzzy front end. This is the purpose of this research note.

In order to increase knowledge on how the fuzzy front end can be better managed, we conducted a large-scale survey of the empirical literature on the fuzzy front end. In total, 39 research articles constitute the base of our review. Analysis of these articles identified 17 success factors for managing the fuzzy front end. The factors are not presented in order of importance, as the present state of knowledge makes such an ordering judgemental at best.

1. *The presence of idea visionaries or product champions.* Such persons can overcome stability and inertia and thus secure the progress of an emerging product concept.
2. *An adequate degree of formalization.* Formalization promotes stability and reduces uncertainty. The fuzzy front end process should be explicit, widely known among members of the organization, characterized by clear decision-making responsibilities, and contain specific performance measures.
3. *Idea refinement and adequate screening of ideas.* Firms need mechanisms to separate good ideas from the less good ones, but also to screen ideas by means of both business and feasibility analysis.
4. *Early customer involvement.* Customers can help to construct clear project objectives, reduce uncertainty and equivocality, and also facilitate the evaluation of a product concept.
5. *Internal cooperation among functions and departments.* A new product concept must be able to 'survive' criticism from different functional perspectives, but cooperation among functions and departments also creates legitimacy for a new concept and facilitates the subsequent development phase.

6. *Information processing other than cross-functional integration and early customer involvement.* Firms need to pay attention to product ideas of competitors, as well as legally mandated issues in their emerging product concepts.
7. *Senior management involvement.* A pre-development team needs support from senior management to succeed, but senior management can also align individual activities which cut across functional boundaries.
8. *Preliminary technology assessment.* Technology assessment means asking early whether the product can be developed, what technical solutions will be required, and at what cost. Firms need also to judge whether the product concept, once turned into a product, can be manufactured.
9. *Alignment between NPD and strategy.* New concepts must capitalize on the core competence of their firms, and synergy among projects is important.
10. *An early and well-defined product definition.* Product concepts are representations of the goals for the development process. A product definition includes a product concept, but in addition provides information about target markets, customer needs, competitors, technology, resources, etc. A well-defined product definition facilitates the subsequent development phase.
11. *Beneficial external cooperation with others than customers.* Many firms benefit from a 'value-chain perspective' during the fuzzy front end, e.g. through collaboration with suppliers. This factor is in line with the emerging literature on 'open innovation'.
12. *Learning from experience capabilities of the pre-project team.* Pre-project team members need to identify critical areas and forecast their influence on project performance, i.e. through learning from experience.
13. *Project priorities.* The pre-project team needs to be able to make trade-offs among the competing virtues of scope (product functionality), scheduling (timing) and resources (cost). In addition, the team also needs to use a priority criteria list, i.e. a rank ordering of key product features, should it be forced to disregard certain attributes due to e.g. cost concerns.
14. *Project management and the presence of a project manager.* A project manager can lobby for support and resources, and coordinate technical as well as design issues.
15. *A creative organizational culture.* Such a culture allows a firm to utilize the creativity and talents of employees, as well as maintaining a steady stream of ideas feeding into the fuzzy front end.
16. *A cross-functional executive review committee.* A cross-functional team for development is not enough – cross-functional competence is also needed when evaluating product definitions.
17. *Product portfolio planning.* The firm needs to assure sufficient resources to develop the planned projects, as well as 'balancing' its portfolio of new product ideas.

Although successful management of the fuzzy front end requires firms to excel in individual factors and activities, this is a necessary rather than sufficient condition. Firms must also be able to integrate or align different activities and factors, as reciprocal interdependencies exist among different success factors. This is often referred to as 'a holistic perspective', 'interdependencies among factors', or simply as 'fit'. To date, however, nobody seems to know exactly which factors should be integrated, and how this should be achieved. In addition, specific guidelines on how to measure performance in the fuzzy front end are also lacking. Hence, only fragments of a 'theory' for managing the fuzzy front end can be said to be in place.

To make things even more complicated, the fuzzy front end process seems to vary not only among firms, but also among projects within the same firm where activities, their sequencing, degree of overlap and relative time duration differ from project to project. Therefore, capabilities for managing the fuzzy front end are both highly valuable yet difficult to obtain. Developing firms therefore need first to obtain proficiency in individual success factors. Second, they need to integrate and arrange these factors into a coherent whole aligned to the circumstances of the firm. And finally, they need to master several trade-off situations which we refer to as 'balancing acts'.

As a first balancing act, firms need to ask if screening of ideas should be made gentle or harsh. On the one hand, firms need to get rid of bad ideas quickly, to save the costs associated with their further development. On the other hand, harsh screening may also kill good ideas too early. Ideas for new products often refine and gain momentum through informal discussion, a fact which forces firms to balance too gentle and too harsh screening. Another balancing act concerns formalization. The basic proposition is that formalization is good because it facilitates transparency, order and predictability. However, in striving to enforce effectiveness, formalization also risks inhibiting innovation and flexibility. Even if evidence is still scarce the relationship between formality and performance seems to obey an inverted U-shaped curve, where both too little and too much formality has a negative effect on performance. From this it follows that firms need to carefully consider the level of formalization they impose on the fuzzy front end.

A third balancing act concerns the trade-off between uncertainty and equivocality reduction. Market and technological uncertainty can often be reduced through environmental scanning and increased information processing in the development team, but more information often increases the level of equivocality. An equivocal situation is one where multiple meanings exist, and such a situation implies that a firm needs to construct, cohere or enact a reasonable interpretation to be able to move on, rather than to engage in information seeking and analysis. Therefore, firms need to balance their need to reduce uncertainty with the need to reduce equivocality, as trying to reduce one often implies increasing the other. Furthermore, firms need to balance the need for allowing for flexibility in the product definition, with the need to push it to closure. A key objective in the fuzzy front end is a clear, robust and unambiguous product definition as such a definition facilitates the subsequent development phase. However, product features often need to be changed during development as market needs change or problems with underlying technologies are experienced. Finally, a final balancing act concerns the trade-off between the competing virtues of innovation and resource efficiency. In essence, this concerns balancing competing value orientations, where innovation and creativity in the front end are enabled by organizational slack and an emphasis on people management, while resource efficiency is enabled by discipline and an emphasis on process management.

In addition, the fuzzy front end process needs to be adapted to the type of product under development. For physical products, different logics apply to assembled and non-assembled products. Emerging research shows that a third logic applies to the development of new service concepts. To conclude, managing the fuzzy front end is indeed no easy task, but can have an enormous positive impact on performance for those firms that succeed.

Source: Frishammar, J. and H. Florén (2008). Where new product development begins: success factors, contingencies and balancing acts in the fuzzy front end. Paper presented at the IAMOT conference in Dubai, 5–8 April. Reproduced by permission of Johan Frishammar (Luleå University of Technology, Sweden) and Henrik Florén (Halmstad University, Sweden).

8.2 Forecasting innovation

Forecasting the future has a pretty bad track record (see Box 8.1), but nevertheless has a central role in business planning for innovation. In most cases the outputs, that is the predictions made, are less valuable than the process of forecasting itself. If conducted in the right spirit, forecasting should provide a framework for gathering and sharing data, debating interpretations and making assumptions, challenges and risks more explicit.

The most appropriate choice of forecasting method will depend on:

- What we are trying to forecast.
- Rate of technological and market change.
- Availability and accuracy of information.
- The company's planning horizon.
- The resources available for forecasting.

BOX 8.1

Limits of forecasting

In 1986, Schnaars and Berenson published an assessment of the accuracy of forecasts of future growth markets since the 1960s, with the benefit of over 20 years of hindsight. The list of failures is as long as the list of successes. Below are some of the failures.

> The 1960s were a time of great economic prosperity and technological advancement in the United States…One of the most extensive and widely publicized studies of future growth markets was TRW Inc. 'Probe of the Future'. The results . . . appeared in many business publications in the late 1960s…Not all…were released. Of the ones that were released, nearly all were wrong! Nuclear-powered underwater recreation centers, a 500 kilowatt nuclear power plant on the moon, 3D color TV, robot soldiers, automatic vehicle control on the interstate system, and plastic germproof houses were amongst some of the growth markets identified by this study.
>
> In 1966, industry experts predicted, 'The shipping industry appears ready to enter the jet age.' By 1968, large cargo ships powered by gas turbine engines were expected to penetrate the commercial market. The benefits of this innovation were greater reliability, quicker engine starts and shorter docking times.
>
> Even dentistry foresaw technological wonders...in 1968, the Director of the National Institute of Dental Research, a division of the US Public Health Service, predicted that 'in the next decade, both tooth decay and the most prevalent form of gum disease will come to a virtual end'. According to experts at this agency, by the late 1970s false teeth and dentures would be 'anachronisms' replaced by plastic teeth implant technology. A vaccine against tooth decay would also be widely available and there would be little need for dental drilling.

Source: Schnaars, S. and C. Berenson (1986) Growth market forecasting revisited: a look back at a look forward. *California Management Review*, **28**, 71–88.

In practice there will be a trade-off between the cost and robustness of a forecast. The more common methods of forecasting such as trend extrapolation and time series are of limited use for new products, because of the lack of past data. However, regression analysis can be used to identify the main factors driving demand for a given product, and therefore provide some estimate of future demand, given data on the underlying drivers.

For example, a regression might express the likely demand for the next generation of digital mobile phones in terms of rate of economic growth, price relative to competing systems, rate of new business formation, and so on. Data are collected for each of the chosen variables and coefficients for each derived from the curve that best describes the past data. Thus the reliability of the forecast depends a great deal on selecting the right variables in the first place. The advantage of regression is that, unlike simple extrapolation or time-series analysis, the forecast is based on cause and effect relations. Econometric models are simply bundles of regression equations, including their interrelationship. However, regression analysis is of little use where future values of an explanatory value are unknown, or where the relationship between the explanatory and forecast variables may change.

Leading indicators and analogues can improve the reliability of forecasts, and are useful guideposts to future trends in some sectors. In both cases there is a historical relationship between two trends. For example, new business start-ups might be a leading indicator of the demand for fax machines in six months' time. Similarly, business users of mobile telephones may be an analogue for subsequent patterns of domestic use.

Such 'normative' techniques are useful for estimating the future demand for existing products, or perhaps alternative technologies or novel niches, but are of limited utility in the case of more radical systems innovation. Exploratory forecasting, in contrast, attempts to explore the range of future possibilities. The most common methods are:

- customer or market surveys
- internal analysis, e.g. brainstorming
- Delphi or expert opinion
- scenario development.

Customer or market surveys

Most companies conduct customer surveys of some sort. In consumer markets this can be problematic simply because customers are unable to articulate their future needs. For example, Apple's iPod was not the result of extensive market research or customer demand, but largely because of the vision and commitment of Steve Jobs. In industrial markets, customers tend to be better equipped to communicate their future requirements, and consequently, business-to-business innovations often originate from customers. Companies can also consult their direct sales force, but these may not always be the best guide to future customer requirements. Information is often filtered in terms of existing products and services, and biased in terms of current sales performance rather than long-term development potential.

There is no 'one best way' to identify novel niches, but rather a range of alternatives. For example, where new products or services are very novel or complex, potential users may not be aware of, or able to articulate, their needs. In such cases traditional methods of market research are of little use, and there will be a greater burden on developers of radical new products and services to 'educate' potential users.

Our own research confirms that different managerial processes, structures and tools are appropriate for routine and novel development projects.[3] We discuss this in detail in Chapter 9, when we examine new product and service development. For example, in terms of frequency of use, the most common methods used for high novelty projects are segmentation, prototyping, market experimentation and industry experts; whereas for the less novel projects the most common methods are partnering customers, trend extrapolation and segmentation. The use of market experimentation and industry experts might be expected where market requirements or technologies are uncertain, but the common use of segmentation for such projects is harder to justify. However, in terms of usefulness, there are statistically significant differences in the ratings for segmentation, prototyping, industry experts, market surveys and latent needs analysis. Segmentation is more effective for routine development projects; and prototyping, industry experts, focus groups and latent needs analysis are all more effective for novel development projects.[4] Lead users are particularly effective for anticipating emerging market needs, as demonstrated by the case of 3M.

Internal analysis, e.g. brainstorming

Structured idea generation, or brainstorming, aims to solve specific problems or to identify new products or services. Typically, a small group of experts is gathered together and allowed to interact. A chairman records all suggestions without comment or criticism. The aim is to identify, but not evaluate, as many opportunities or solutions as possible. Finally, members of the group vote on the different suggestions. The best results are obtained when representatives from different functions are present, but this can be difficult to manage. Brainstorming does not produce a forecast as such, but can provide useful input to other types of forecasting.

We discussed a range of approaches to creative problem solving and idea generation in Chapter 3. Most of these are relevant here, and include ways of:[5]

- *Understanding the problem* – the active construction by the individual or group through analysing the task at hand (including outcomes, people, context and methodological options) to determine whether and when deliberate problem-structuring efforts are needed. This stage includes constructing opportunities, exploring data and framing problems.
- *Generating ideas* – to create options in answer to an open-ended problem. This includes generating and focusing phases. During the generating phase of this stage, the person or group produces many options (fluent thinking), a variety of possible options (flexible thinking), novel or unusual options (original thinking) or a number of detailed or refined options (elaborative thinking). The focusing phase provides an opportunity for examining, reviewing, clustering and selecting promising options.
- *Planning for action* – is appropriate when a person or group recognizes a number of interesting or promising options that may not necessarily be useful, valuable or valid. The aim is to make or develop effective choices, and to prepare for successful implementation and social acceptance.

External assessment, e.g. Delphi

The opinion of outside experts, or Delphi method, is useful where there is a great deal of uncertainty or for long time horizons.[6] Delphi is used where a consensus of expert opinion is required on the timing, probability and identification of future technological goals or consumer needs and the factors likely to affect their achievement. It is best used in making long-term forecasts and revealing how new technologies and other factors could trigger discontinuities in technological trajectories. The choice of experts and the identification of their level and area of expertise are important; the structuring of the questions is even more important. The relevant experts may include suppliers, dealers, customers, consultants and academics. Experts in non-technological fields can be included to ensure that trends in economic, social and environmental fields are not overlooked.

The Delphi method begins with a postal survey of expert opinion on what the future key issues will be, and the likelihood of the developments. The response is then analysed, and the same sample of experts resurveyed with a new, more focused questionnaire. This procedure is repeated until some convergence of opinion is observed, or conversely if no consensus is reached. The exercise usually consists of an iterative process of questionnaire and feedback among the respondents; this process finally yields a Delphi forecast of the range of experts' opinions on the probabilities of certain events occurring by a quoted time. The method seeks to nullify the disadvantage of face-to-face meetings at which there could be deference to authority or reputation, a reluctance to admit error, a desire to conform or differences in persuasive ability. All of these could lead to an inaccurate consensus of opinion. The quality of the forecast is highly dependent on the expertise and calibre of the experts; how the experts are selected and how many should be consulted are important questions to be answered. If international experts are used, the exercise can take a considerable length of time, or the number of iterations may have to be curtailed. Although seeking a consensus may be important, adequate attention should be paid to views that differ radically 'from the norm' as there may be important underlying reasons to justify such maverick views. With sufficient design, understanding and resources, most of the shortcomings of the Delphi technique can be overcome and it is a popular technique, particularly for national foresight programmes.

In Europe, governments and transnational agencies use Delphi studies to help formulate policy, usually under the guise of 'Foresight' exercises. In Japan, large companies and the government routinely survey expert opinion in order to reach some consensus in those areas with the greatest potential for long-term development. Used in this way, the Delphi method can to a large extent become a self-fulfilling prophecy.

Scenario development

Scenarios are internally consistent descriptions of alternative possible futures, based upon different assumptions and interpretations of the driving forces of change.[7] Inputs include quantitative data and analysis, and qualitative assumptions and assessments, such as societal, technological, economical, environmental and political drivers. Scenario development is not strictly-speaking prediction, as it assumes that the future is uncertain and that the path of current developments can range from the conventional to the revolutionary. It is particularly good at incorporating potential critical events which might result in divergent paths or branches being pursued.

Scenario development can be normative or explorative. The normative perspective defines a preferred vision of the future and outlines different pathways from the goal to the present. For example, this is commonly used in energy futures and sustainable futures scenarios. The explorative approach defines the drivers of change, and creates scenarios from these without explicit goals or agendas.

For scenarios to be effective they need to inclusive, plausible and compelling (as opposed to being exclusive, implausible or obvious), as well as being challenging to the assumptions of the stakeholders. They should make the assumptions and inputs used explicit, and form the basis of a process of discussion, debate, policy, strategy and ultimately action. The output is typically two or three contrasting scenarios, but the process of development and discussion of scenarios is much more valuable.

Scenario development may involve many different forecasting techniques, including computer-based simulation. Typically, it begins with the identification of the critical indicators, which might include use of brainstorming and Delphi techniques. Next, the reasons for the behaviour of these indicators are examined, perhaps using regression techniques. The future events which are likely to affect these indicators are identified. These are used to construct the best, worst and most-likely future scenarios. Finally, the company assesses the impact of each scenario on its business. The goal is to plan for the outcome with the greatest impact, or better still, retain sufficient flexibility to respond to several different scenarios. Scenario development is a key part of the long-term planning process in those sectors characterized by high capital investment, long lead times and significant environmental uncertainty, such as energy, aerospace and telecommunications.

RESEARCH NOTE The pre-diffusion phase

The S-shaped diffusion curve is empirically observed for a broad range of new products such as the telephone, hybrid corn and the microwave oven. However, a critical, but under-researched issue in diffusion research is what happens *before* this well-known S-shaped diffusion curve. From a managerial perspective it is important to realize that diffusion requires that several conditions have to be met: for example, products have to be developed, produced, distributed and the necessary infrastructural arrangements have to be in place. It is seldom realized, however, that prior to any S-shaped diffusion curve, the market introduction of a new product is more typically followed by an erratic pattern of diffusion, referred to as the pre-diffusion phase. The lack of attention to this so-called pre-diffusion phase is one of the main limitations of mainstream research and practice.

1. The pre-diffusion phase for new products

We define the pre-diffusion phase to begin after the market introduction of the first new product and to end when the diffusion of this type of product takes off, i.e. when the regular S-shaped diffusion curve begins. After the introduction of the first product, instead of a smooth S-curve, in practice an erratic process of diffusion may occur. In this situation the market is unstable. In the field of telecommunications, for example, the diffusion of new communication products and services often starts with the periodic introduction, decline and re-introduction of product variants in multiple small-scale applications before mainstream applications and product designs appear and the diffusion takes off.

The table below shows estimates of the length of the pre-diffusion phase for a sample of products from different industries.

Length of the pre-diffusion phase of products from different industries

Product	Industry	Market introduction	Diffusion begins	Length of pre-diffusion phase (years)
Jet engine	Aerospace and defence	1941	1943	2
Radar		1934	1939	5
ABS	Automobile and parts	1959	1978	19
Airbag		1972	1988	16
Memory metal	Materials, compound and metals	1968	1972	4
Dyneema		1975	1990	15
Flash memory	IT and telecommunications hardware and software	1988	2001	13
Mobile telephony		1946	1983	37
Transistor	Electronic components & equipment	1949	1953	4
Television		1939	1946	7
Contraceptive pill	Medical equipment and medicines	1928	1962	34
MRI		1980	1983	3
Microwave oven	Personal goods and household equipment	1947	1955	8
Air conditioning		1902	1915	13
				Average = 13
				St dev = 11

Data in the table are derived from multiple sources and are based on original work from J.R. Ortt (2004, 2008).

From the table we can see that a significant pre-diffusion phase exists for most types of innovation. The average length of this phase for the sample of products is more than a decade. Moreover, the data shows that, even within industries, the variation in the length of the pre-diffusion phase is considerable.

2. Different perspectives on, and main causes of, the occurrence of the pre-diffusion phase

The pre-diffusion phase has been described from different scientific perspectives, each of which proposes alternative causes of this phase. Marx, for example, is an economist who more than 150 years ago described why it takes so long to implement new methods of production in companies and why these new methods at first diffuse remarkably slowly among companies in an industry. Marx focuses on the supply side of the market when describing the diffusion of these methods of production (so-called capital goods). From this perspective, the pre-diffusion phase is seen as a kind of trial-and-error process that is required to improve the production methods and to adapt these methods to the prevailing way of working in companies (and the other way around) before these methods become profitable.

About a century later, diffusion researchers took a different perspective and focused on the demand side of the market (Rogers, 2003). These researchers, mostly sociologists, tend to see the diffusion process as a communication process in a population or a segment of customers. The researchers have a bias towards the smooth S-shaped diffusion curve, but upon closer inspection their findings also indicate how demand-side factors may cause a pre-diffusion phase. Characteristics of subsequent groups of customers are often assessed in diffusion research. The very first group of customers, the innovators, are often deviant from the remainder of the potential customers and thereby might hamper the communication process that is required for diffusion.

Moore (2002) elaborates on this idea and concludes that a 'chasm' occurs between subsequent groups of customers. Moore focuses on the interaction of the demand and supply side of the market when he explains this chasm. The first types of customers, referred to as technology enthusiasts and visionaries, are customers willing to experiment with the product. Mainstream customers, however, hardly communicate with these sub-segments, so the diffusion does not proceed smoothly. Moreover, the mainstream customers want completely different product versions: they want reliable, foolproof and complete packages of products and services. Rather than testing these requirements themselves, they prefer to see how well-known companies or customers have already successfully implemented the product in their process of working. The technology enthusiasts or visionaries cannot fulfil this role and a chasm therefore occurs.

3. Main managerial consequences of the pre-diffusion phase

Each of these perspectives has its own way of explaining why this phase is managerially important. Marx' perspective implies that large-scale diffusion of new production methods is often preceded by considerable periods of experimentation. The costs incurred in this pre-diffusion phase can be considerable; the profits for the first company that in an economically viable way masters the application of these methods can be very large as well. Marx' perspective illustrates the importance of managing the innovation process before the implementation of new methods of production. Chasms in the diffusion process, noticed by Rogers and Moore, indicate that market introduction strategies of new products are crucially important as well. Segments of potential customers may be hard to distinguish and subsequent segments of customers may require completely different product variants and business models and thereby hamper the smooth diffusion process.

From a management perspective, the pre-diffusion phase is very risky. It is remarkable how many companies involved in the invention of new products lose out. About half of the pioneers that are first to introduce a *successful* product in the market, fail and vanish before their product diffuses on a large scale. One of the main reasons is that the pre-diffusion phase can last a very long time. In general, the pre-diffusion phase requires considerable investment yet does not generate the same amount of income. The existence of the pre-diffusion phase has profound managerial implications: it shows that introducing a new product usually is a matter of deep pockets and long breath.

From: J. Roland Ortt, and partly based on Ortt & Schoormans (2004) and Ortt & Delgoshaie (2008).

Marx, K. (1867) *Capital: A Critique of Political Economy*, Penguin edition, Middlesex, 1976; Moore, G.A. (2002) *Crossing the Chasm. Marketing and Selling Disruptive Products to Mainstream Customers*, HarperCollins, New York; Ortt, J.R. and N. Delgoshaie (2008) Why does it take so long before the diffusion of new high-tech products takes off? In B. Abu-Hijleh, M. Arif, T. Khalil and Y. Hosni, eds, *Proceedings of the 17th International Conference on Management of Technology* (6–10 April), Dubai; Ortt, J.R. and J.P.L. Schoormans (2004) The pattern of development and diffusion of breakthrough communication technologies. *European Journal of Innovation Management*, 7 (4), 292–302; Rogers, E.M. (2003) *Diffusion of Innovations*, fifth edition, Free Press, New York.

8.3 Estimating the adoption of innovations

A better understanding of why and how innovations are adopted (or not) can help us to develop more realistic plans. As the Research Note on the chasm between development and successful adoption shows, around half of all innovations never reach the intended markets. Conventional marketing approaches are fine for many products and services, but not for innovations. Marketing texts often refer to ‘early adopters’ and ‘majority adopters’, and even go so far as to apply numerical estimates of these, but these simple categories are based on the very early studies of the state-sponsored diffusion of hybrid-seed varieties in farming communities, and are far from universally applicable. To better plan for innovations we need a deeper understanding of what factors promote and constrain adoption, and how these influence the rate and level of diffusion within different markets and populations.

There are many barriers to the widespread adoption of innovations, including:

- *Economic* – personal costs versus social benefits, access to information, insufficient incentives.
- *Behavioural* – priorities, motivations, rationality, inertia, propensity for change or risk.
- *Organizational* – goals, routines, power and influence, culture and stakeholders.
- *Structural* – infrastructure, sunk costs, governance.

For these reasons, historically, large complex socio-technical systems tend to change only incrementally. However, more radical transformations can occur, but these often begin in strategic niches, with different goals, needs, practices and processes. As these niches demonstrate and develop the innovations, through social experimentation and learning, they may begin to influence or enter the mainstream. This may be through whole new market niches, or by forming hybrid markets between the niche and mainstream.

Rogers' definition of diffusion is used widely: '*the process by which an innovation is communicated through certain channels over time among members of a social system. It is a special type of communication, in that the messages are concerned with new ideas*'.[4] However, there are no generally accepted definitions of associated terms such as 'technology transfer', 'adoption', 'implementation' or 'utilization'. Diffusion usually involves the analysis of the spread of a product or idea in a given social system, whereas technology transfer is usually a point-to-point phenomenon. Technology transfer usually implies putting information to use, or more specifically moving ideas from the laboratory to the market. The distinction between adoption, implementation and utilization is less clear. Adoption is generally considered to be the decision to acquire something, whereas implementation and utilization imply some action and adaptation.

The literature on diffusion is vast and highly fragmented. However, a number of different approaches to diffusion research can be identified, each focusing on particular aspects of diffusion and adopting different methodologies. The main contributions have been from economics, marketing, sociology and anthropology. Economists have developed a number of econometric models on the diffusion of new products and processes in an effort to explain past behaviour and to predict future trends. Prediction is a common theme of the marketing literature. Marketing studies have adopted a wide range of different research instruments to examine buyer behaviour, but most recent research has focused on social and psychological factors. Development economics and rural sociology have both examined the adoption of agricultural innovations, using statistical analysis of secondary data and collection of primary data from surveys. Much of the anthropological research has been based on case studies of the diffusion of new ideas in tribes, villages or communities. Most recently, there has been a growing number of multidisciplinary studies which have examined the diffusion of educational, medical and other policy innovations.

Processes of diffusion

Research on diffusion attempts to identify what influences the rate and direction of adoption of an innovation. The diffusion of an innovation is typically described by an S-shaped (logistic) curve (Figure 8.1). Initially, the rate of adoption is low, and adoption is confined to so-called 'innovators'. Next to adopt are the 'early adopters', then the 'late majority', and finally the curve tails off as only the 'laggards' remain. Such taxonomies are fine with the benefit of hindsight, but provide little guidance for future patterns of adoption.[8]

Hundreds of marketing studies have attempted to fit the adoption of specific products to the S-curve, ranging from television sets to new drugs. In most cases mathematical techniques can provide a relatively good fit with historical data, but research has so far failed to identify robust generic models of adoption. In practice the precise pattern of adoption of an innovation will depend on the interaction of demand-side and supply-side factors:

- *Demand-side factors* – direct contact with or imitation of prior adopters, adopters with different perceptions of benefits and risk.
- *Supply-side factors* – relative advantage of an innovation, availability of information, barriers to adoption, feedback between developers and users.

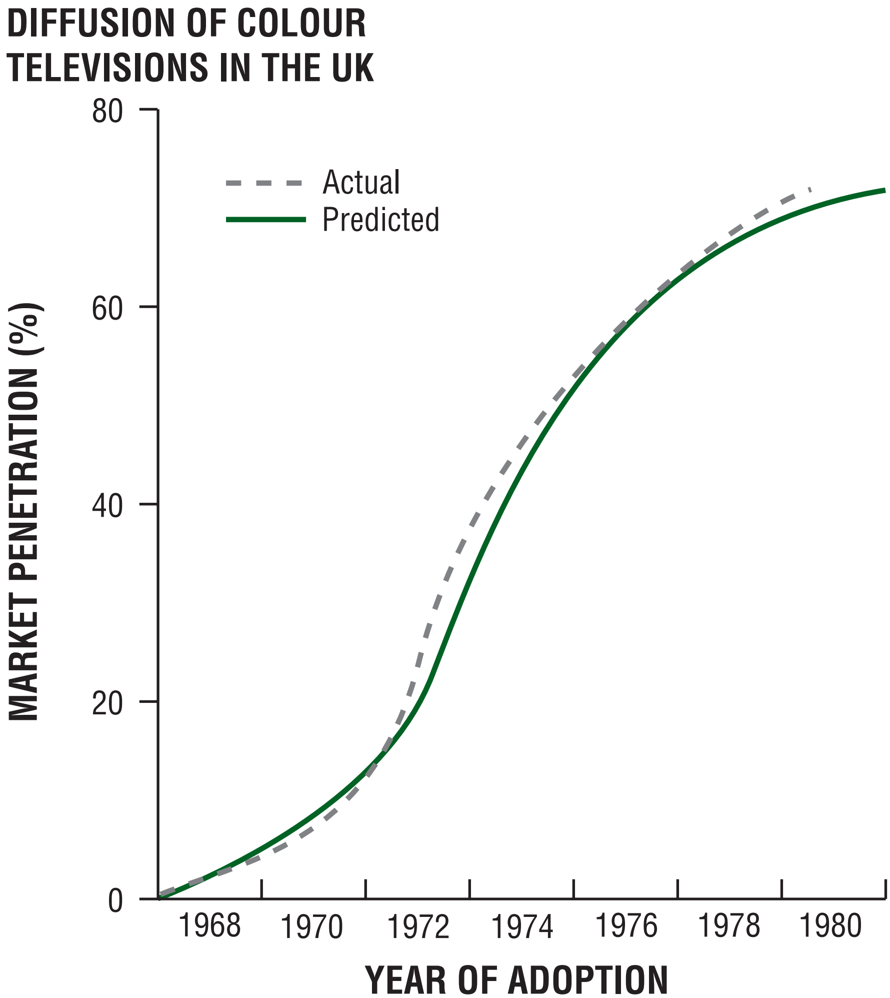


FIGURE 8.1: Typical diffusion S-curve for the adoption of an innovation
Source: Meade, N. and Islam, T. (2006), 'Modeling and forecasting the diffusion of innovation – a 25 year review', *International Journal of Forecasting*, 22 (3), 519–545.

The epidemic S-curve model is the earliest and is still the most commonly used. It assumes a homogeneous population of potential adopters, and that innovations spread by information transmitted by personal contact, observation and the geographical proximity of existing and potential adopters. This model suggests that the emphasis should be on communication, and the provision of clear technical and economic information. However, the epidemic model has been criticized because it assumes that all potential adopters are similar and have the same needs, which is unrealistic.

The Probit model takes a more sophisticated approach to the population of potential adopters. It assumes that potential adopters have different threshold values for costs or benefits, and will only adopt beyond some critical or threshold value. In this case differences in threshold values are used to explain different rates of adoption. This suggests that the more similar potential adopters are, the faster the diffusion.

However, adopters are assumed to be relatively homogeneous, apart from some difference in progressiveness or threshold values. Supply-side models do not consider the possibility that the rationality and the profitability of adopting a particular innovation might be different for different adopters. For example, local 'network externalities' such as the availability of trained skilled users, technical assistance and maintenance, or complementary technical or organizational innovations are likely to affect the cost of adoption and use, as distinct from the cost of purchase.

Also, it is unrealistic to assume that adopters will have perfect knowledge of the value of an innovation. Therefore Bayesian models of diffusion introduce lack of information as a constraint to diffusion. Potential adopters are allowed to hold different beliefs regarding the value of the innovation, which they may revise according to the results of trials to test the innovation. Because these trials are private, imitation cannot take place and other potential adopters cannot learn from the trials. This suggests better-informed potential adopters may not necessarily adopt an innovation earlier than the less well informed, which was an assumption of earlier models.[9]

Slightly more realistic assumptions, such as those of the Bass model, include two different groups of potential adopters: innovators, who are not subject to social emulation; and imitators, for whom the diffusion process takes the epidemic form. This produces a skewed S-curve because of the early adoption by innovators, and suggests that different marketing processes are needed for the innovators and subsequent imitators. The Bass model is highly influential in economics and marketing research, and the distinction between the two types of potential adopters is critical in understanding the different mechanisms involved in the two user segments.

Bandwagons may occur where an innovation is adopted because of pressure caused by the sheer number of those who have already adopted an innovation, rather than by individual assessments of the benefits of an innovation. In general, as soon as the number of adopters has reached a certain threshold level, the greater the level of ambiguity of the innovation's benefits, the greater the subsequent number of adopters. This process allows technically inefficient innovations to be widely adopted, or technically efficient innovations to be rejected. Examples include the QWERTY keyboard, originally designed to prevent professional typists from typing too fast and jamming typewriters; and the DOS operating system for personal computers, designed by and for computer enthusiasts.

Bandwagons occur due to a combination of competitive and institutional pressures.[10] Where competitors adopt an innovation, a firm may adopt because of the threat of lost competitiveness, rather than as a result of any rational evaluation of benefits. For example, many firms adopted flexible manufacturing systems (FMS) in the 1980s in response to increased competition, but most failed to achieve significant benefits. The main institutional pressure is the threat of lost legitimacy, for example, being considered by peers or customers as being less progressive or competent.[11]

The critical difference between bandwagons and other types of diffusion is that they require only limited information to flow from early to later adopters. Indeed, the more ambiguous the benefits of an innovation, the more significant bandwagons are on rates of adoption. Therefore the process of diffusion must be managed with as much care as the process of development. In short, better products do not necessarily result in more sales. Not everybody requires a better mousetrap.

Finally, there are more sociological and psychological models of adoption, which are based on interaction and feedback between the developers and potential adopters.[12] These perspectives consider how individual psychological characteristics such as attitude and perception affect adoption. Individual motivations, perceptions, likes and dislikes determine what information is reacted to and how it is processed. Potential adopters will be guided and prejudiced by experience, and will have 'cognitive maps' which filter information and guide behaviour. Social context will also influence individual behaviour. Social structures and meaning systems are locally constructed, and therefore highly context-specific. These can distort the way in which information is interpreted and acted upon. Therefore the perceived value of an innovation, and hence its subsequent adoption, is not some objective fact, but instead depends on individual psychology and social context. These factors are particularly important in the later stages of diffusion. For example, lifestyle aspirations, such as having more exercise and adopting a healthy diet have created the opportunity for many new products and services. Initially relying on local demand in North London and word-of-mouth recommendations, the fruit drink company Innocent Smoothies became a global phenomenon. It successfully anticipated a demand for convenient fruit consumption which the existing multinationals such as and Nestlé missed .

Initially, the needs of early adopters or innovators dominate, and therefore the characteristics of an innovation are most important. Innovations tend to evolve over time through improvements required by these early users, which may reduce the relative cost to later adopters. However, early adopters are almost by definition 'atypical', for example, they tend to have superior technical skills. As a result the preferences of early adopters can have a disproportionate impact on the subsequent development of an innovation, and result in the establishment of inferior technologies or abandonment of superior alternatives.

Factors influencing adoption

Numerous variables have been identified as affecting the diffusion and adoption of innovations, but these can be grouped into three clusters: characteristics of the innovation itself; characteristics of individual or organizational adopters; and the characteristics of the environment. Characteristics of an innovation found to influence adoption include relative advantage, compatibility, complexity, observability and trialability. Individual characteristics include age, education, social status and attitude to risk. Environmental and institutional characteristics include economic factors such as the market environment and sociological factors like communications networks. However, whilst there is a general agreement regarding the relevant variables, there is very little consensus on the relative importance of the different variables, and in some cases disagreements over the direction of relationships.

Characteristics of an innovation

A number of characteristics of an innovation have been found to affect diffusion and adoption:[4]

- relative advantage
- compatibility
- complexity
- trialability
- observability.

Relative advantage

Relative advantage is the degree to which an innovation is perceived as better than the product it supersedes, or competing products. Relative advantage is typically measured in narrow economic terms, for example cost or financial payback, but non-economic factors such as convenience, satisfaction and social prestige may be equally important. In theory, the greater the perceived advantage, the faster the rate of adoption.

It is useful to distinguish between the primary and secondary attributes of an innovation. Primary attributes, such as size and cost, are invariant and inherent to a specific innovation irrespective of the adopter. Secondary attributes, such as relative advantage and compatibility, may vary from adopter to adopter, being contingent upon the perceptions and context of adopters. In many cases, a so-called 'attribute gap' will exist. An attribute gap is the discrepancy between a potential user's perception of an attribute or characteristic of an item of knowledge and how the potential user would prefer to perceive that attribute. The greater the sum of all attribute gaps, the less likely a user is to adopt the knowledge. This suggests that preliminary testing of an innovation is desirable in order to determine whether significant attribute gaps exist. Not all attribute gaps require changes to the innovation itself – a distinction needs to be made between knowledge content and knowledge format. The idea of pre-testing information for the purposes of enhancing its value and acceptance is not widely practised.

Compatibility

Compatibility is the degree to which an innovation is perceived to be consistent with the existing values, experience and needs of potential adopters. There are two distinct aspects of compatibility: existing skills and practices; and values and norms. The extent to which the innovation fits the existing skills, equipment, procedures and performance criteria of the potential adopter is important, and relatively easy to assess.

However, compatibility with existing practices may be less important than the fit with existing values and norms.[13] Significant misalignments between an innovation and an adopting organization will require changes in the innovation or organization, or both. In the most successful cases of implementation, mutual adaptation of the innovation and organization occurs.[14] However, few studies distinguish between compatibility with value and norms, and compatibility with existing practices. The extent to which the innovation fits the existing skills, equipment, procedures and performance criteria of the potential adopter is critical. Few innovations initially fit the user environment into which they are introduced. Significant misalignments between the innovation and the adopting organization will require changes in the innovation or organization, or in the most successful cases of implementation, mutual adaptation of both. Initial compatibility with existing practices may be less important, as it may provide limited opportunity for mutual adaptation to occur.

Complexity

Complexity is the degree to which an innovation is perceived as being difficult to understand or use. In general, innovations which are simpler for potential users to understand will be adopted more rapidly than those which require the adopter to develop new skills and knowledge.

However, complexity can also influence the direction of diffusion. Evolutionary models of diffusion focus on the effect of 'network externalities', that is the interaction of consumption, pecuniary and technical factors which shape the diffusion process. For example, within a region the cost of adoption and use, as distinct from the cost of purchase, may be influenced by: the availability of information about the technology from other users, of trained skilled users, technical assistance and maintenance, and of complementary innovations, both technical and organizational.

Trialability

Trialability is the degree to which an innovation can be experimented with on a limited basis. An innovation that is trialable represents less uncertainty to potential adopters, and allows learning by doing. Innovations which can be trialled will generally be adopted more quickly than those which cannot. The exception is where the undesirable consequences of an innovation appear to outweigh the desirable characteristics. In general, adopters wish to benefit from the functional effects of an innovation, but avoid any dysfunctional effects. However, where it is difficult or impossible to separate the desirable from the undesirable consequences trialability may reduce the rate of adoption.

Developers of an innovation may have two different motives for involving potential users in the development process. First, to acquire knowledge from the users needed in the development process, to ensure usability and to add value. Second, to attain user 'buy-in', that is user acceptance of the innovation and commitment to its use. The second motive is independent of the first, because increasing user acceptance does not necessarily improve the quality of the innovation. Rather, involvement may increase users' tolerance of any inadequacies. In the case of point-to-point transfer, typically both motives are present.

However, in the case of diffusion it is not possible to involve all potential users, and therefore the primary motive is to improve usability rather than attain user buy-in. But even the representation of user needs must be indirect, using surrogates such as specially selected user groups. These groups can be problematic for a number of reasons. First, because they may possess atypically high levels of technical knowledge, and therefore are not representative. Second, where the group must represent diverse user needs, such as both experienced and novice users, the group may not work well together. Finally, when user representatives work closely with developers over a long period of time they may cease to represent users, and instead absorb the developer's viewpoint. Thus, there is no simple relationship between user involvement and user satisfaction. Typically, very low levels of user involvement are associated with user dissatisfaction, but extensive user involvement does not necessarily result in user satisfaction.

Observability

Observability is the degree to which the results of an innovation are visible to others. The easier it is for others to see the benefits of an innovation, the more likely it will be adopted. The simple epidemic model of diffusion assumes that innovations spread as potential adopters come into contact with existing users of an innovation.

Peers who have already adopted an innovation will have what communication researchers call 'safety credibility', because potential adopters seeking their advice will believe they know what it is really like to implement and utilize the innovation. Therefore early adopters are well positioned to disseminate 'vicarious learning' to their colleagues. Vicarious learning is simply learning from the experience of others, rather than direct personal experimental learning. However, the process of vicarious learning is neither inevitable nor efficient because, by definition, it is a decentralized activity. Centralized systems of dissemination tend to be designed and rewarded on the basis of being the source of technical information, rather than for facilitating learning among potential adopters.

Over time learning and selection processes foster both the evolution of the technologies to be adopted and the characteristics of actual and potential adopters. Thus an innovation may evolve over time through improvements made by early users, thereby reducing the relative cost to later adopters. In addition, where an innovation requires the development of complementary features, for example a specific infrastructure, late adopters will benefit. This suggests that instead of a single diffusion curve, a series of diffusion curves will exist for the different environments. However, there is a potential drawback to this model. The short-term preferences of early adopters will have a disproportionate impact on the subsequent development of the innovation, and may result in the establishment of inferior technologies and abandonment of superior alternatives. In such cases interventionist policies may be necessary to postpone the lock-in phenomenon.

From a policy perspective, high visibility is often critical. However, high visibility, at least initially, may be counter-productive. If users' expectations about an innovation are unrealistically high and adoption is immediate, subsequent disappointment is likely. Therefore in some circumstances it may make sense to delay dissemination or to slow the rate of adoption. However, in general researchers and disseminators are reluctant to withhold knowledge.

The choice between the different models of diffusion and factors that will most influence adoption will depend on the characteristics of the innovation and nature of potential adopters. The simple epidemic model appears to provide a good fit to the diffusion of new processes, techniques and procedures, whereas the Bass model appears to best fit the diffusion of consumer products. However, the mathematical structure of the epidemic and Bass models tends to overstate the importance of differences in adopter characteristics, and tends to underestimate the effect of macroeconomic and supply-side factors. In general, both these models of diffusion work best where the total potential market is known, that is for derivatives of existing products and services, rather than totally new innovations.

In the case of systemic or network innovations, a wider range of factors have to be managed to promote adoption and diffusion. In such cases a wider set of actors and institutions on the supply and demand side are relevant, in what has been called an adoption network.[15] On the supply side, other organizations may provide the infrastructure, support and complementary products and services which can promote or prevent adoption and diffusion. For example, in 2008 the two-year battle between the new high-definition DVD formats was decided not by price or any technical superiority, but rather because the Blu-ray consortium managed to recruit more film studios to its format than the competing HD-DVD format. As soon as the uncertainty over the future format was resolved, there was a step change increase in the rate of adoption.

On the demand side, the uncertainty of potential adopters, and communication with and between them needs to be managed. Whilst early adopters may emphasize technical performance and novelty above other factors, the mainstream mass market is more likely to be concerned with factors such as price, quality, convenience and support. This transition from the niche market and needs of early adopters, through to the requirements of more mass markets has been referred to as crossing the chasm by Moore.[16] Moore studied the successes and many more failures of Silicon Valley and other high-technology products, and argued that the critical success factors for early adopters and mass markets were fundamentally different, and most innovations failed to make this transition. Therefore the successful launch and diffusion of a systemic or network innovation demands attention to traditional marketing issues such as the timing and positioning of the product or service,[17] but also significant effort to demand-side factors such as communication and interactions between potential adopters.[18]

The continued improvement in health in the advanced economies over the past 50 years can be attributed in part to the supply of new diagnostic techniques, drugs and procedures, but also to changes in the demand side, such as increases in education, income and service infrastructure. However, the focus of innovation (and policy) in healthcare is too often on the development and commercialization of new pharmaceuticals, but this is only a part of the story. This is a clear case of systemic innovation, in which firm and public R&D are necessary, but not sufficient to promote improved health. The adoption network includes regulatory bodies, national health assessment and reference pricing schemes, regional health agencies, public and private insurers, as well as the more obvious hospitals, doctors, nurses and patients.[19] However, too often the management and policy for innovation in health is confined to regulation of prices and effects of intellectual property regimes.[20] There is a clear need for new methods of interaction, involvement and engagement in such cases.[21]

Diffusion research and practice has been criticized for an increasingly limited scope and methodology. Rogers identifies a number of shortcomings of research and practice:[4]

1. Diffusion has been seen as a *linear, unidirectional communication* activity in which the active source of research or information attempts to influence the attitudes and/or behaviours of essentially passive receivers. However, in most cases diffusion is an interactive process of adaptation and adoption.
2. Diffusion has been viewed as a *one-to-many communication* activity, but point-to-point transfer is also important. Both centralized and decentralized systems exist. Decentralized diffusion is a process of convergence as two or more individuals exchange information in order to move toward each other in the meanings they ascribe to certain events.
3. Diffusion research has been preoccupied with an *action-centred and issue-centred communication* activity, such as selling products, actions or policies. However, diffusion is also a social process, affected by social structure and position and interpersonal networks.
4. Diffusion research has used *adoption as the dependent variable* – the decision to use the innovation, rather than implementation itself – the consequences of the innovation. Most studies have used attitudinal change as the dependent variable, rather than change in overt behaviour.
5. Diffusion research has suffered from an implicit *pro-innovation bias*, which assumes that an innovation should be adopted by all members of a social system as rapidly as possible. Therefore the process of adaptation or rejection of an innovation has been overlooked, and there have been relatively few studies of how to prevent the diffusion 'bad' innovations.

RESEARCH NOTE Why innovations fail to be adopted

This research examined the factors which influence the adoption and diffusion of innovations drawing upon case studies of successful and less successful consumer electronics products, such as the Sony PlayStation and MiniDisc, Apple iPod and Newton, TomTom GO, TiVo and RIM Blackberry.

The study finds that a critical factor influencing successful diffusion is the careful management of acceptance by the early adopters, which in turn influences the adoption by the main market. Strategic issues such as positioning, timing and management of the adoption network are identified as being important. The adoption network is defined as a configuration of users, peers, competitors, and complementary products and services and infrastructure. However, the positioning, timing and adoption networks are different for the early and main market adopters, and failure to recognize these differences is a common cause of the failure of innovations to diffuse widely. Also, innovation contingencies such as the degree of radicalness and discontinuity affect how these factors interact and how these need to be managed to promote acceptance. The relevant assessment of the radicalness and discontinuity of an innovation is not based on the technological aspects, but rather the effects on user behaviour and consumption.

To promote use by early adopters, the research recommends that four enabling factors need to be managed: legitimize the innovation through reference customers and visible performance advantage; trigger word of mouth within specialist communities of practice; stimulate imitation to increase the user base and peer pressure; and collaborate with opinion leaders. Significantly, the study argues that the subsequent successful diffusion of an innovation into the mainstream market has very little to do with the merits of the product itself, and much more to do with the positive acceptance of early adopters and repositioning and targeting for the main market by influencing the relevant adoption network.

Source: Frattini, F. (2008) The commercialisation of innovation in high-tech markets, PhD thesis, Politecnico di Milano, Italy.

8.4 Assessing risk, recognizing uncertainty

Dealing with risk and uncertainty is central to the assessment of most innovative projects. Risk is usually considered to be possible to estimate, either qualitatively – high, medium, low – or ideally by probability estimates. Uncertainty is by definition unknowable, but nonetheless the fields and degree of uncertainty should be identified to help to select the most appropriate methods of assessment and plan for contingencies. Traditional approaches to assessing risk focus on the probability of foreseeable risks, rather than true uncertainty, or complete ignorance – what Donald Rumsfeld memorably called the 'unknown unknowns' (12 February 2002, US Department of Defense news briefing).

Research on new product development and R&D project management has identified a broad range of strategies for dealing with risk. Both individual characteristics and organizational climate influence perceptions of risk and propensities to avoid, accept or seek risks. Formal techniques such as failure mode and effects analysis (FMEA), potential problem analysis (PPA) and fault tree analysis (FTA) have a role, but the broader signals and support from the organizational climate is more important than the specific tools or methods used. For example, too many organizations emphasize project management in order to contain internal risks in the organization, but as a result fail to identify or exploit opportunities to take acceptable risks and to innovate.[22]

There are many approaches to risk assessment, but the most common issues to be managed include:

- Probabilistic estimates of technical and commercial success.
- Psychological (cognitive) and sociological perceptions of risk.
- Political and policy influences, such as the 'precautionary principle'.

Risk as probability

Research indicates that 30–45% of all projects fail to be completed, and over half of projects overrun their budgets or schedules by up to 200%. Figure 8.2 presents the results of a survey of R&D managers. Whilst most appear to be relatively confident when predicting technical issues such as the development time and costs, a much smaller proportion are confident when forecasting commercial aspects of the projects.

We examined how commonly different approaches to project assessment were used in practice. We surveyed 50 projects in 25 companies, and assessed how often different criteria were used, and how useful they were thought to be. Table 8.2 summarizes some of the results. Clearly probabilistic estimates of technical and commercial success are near universal, and considered to be of critical importance in all types of project assessment. These are usually combined with some form of financial assessment, and fit with the company strategy and capabilities.

Given the complexities involved, the outcomes of investments in innovation are uncertain, so that the forecasts (of costs, prices, sales volume, etc.) that underlie project and programme evaluations can

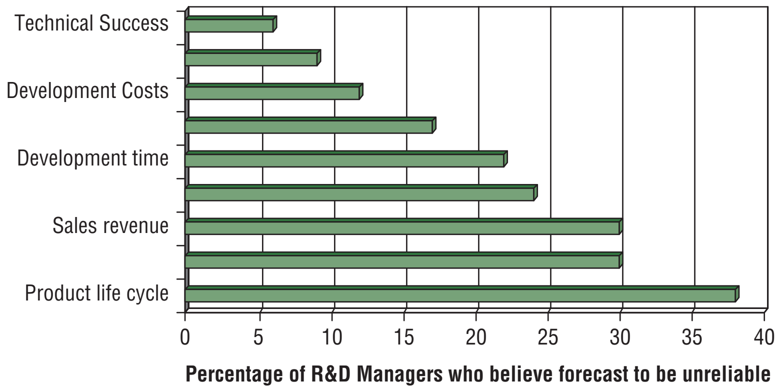


FIGURE 8.2: Uncertainty in project planning
Source: Derived from Freeman, C. and L. Soete (1997) *The Economics of Innovation*, MIT Press, Cambridge, MA.

Table 8.2 Use and usefulness of criteria project screening and selection

	High novelty		Low novelty	
	Usage (%)	Usefulness	Usage (%)	Usefulness
Probability of technical success	100	4.37	100	4.32
Probability of commercial success	100	4.68	95	4.50
Market share*	100	3.63	84	4.00
Core competencies*	95	3.61	79	3.00
Degree of internal commitment	89	3.82	79	3.67
Market size	89	3.76	84	3.94
Competition	89	3.76	84	3.81
NPV/IRR	79	3.47	68	3.92
Payback period/break-even*	79	3.20	58	4.27

Usefulness score: 5 = critical; 0 = irrelevant. * denotes difference in usefulness rating is statistically significant at 5% level.
Source: Adapted from Tidd, J. & K. Bodley (2002) Effect of novelty on new product development processes and tools. *R&D Management*, 32 (2), 127–38. Based on 50 development projects.

be unreliable. According to Joseph Bower, management finds it easier, when appraising investment proposals, to make more accurate forecasts of reductions in production cost than of expansion in sales, whilst their ability to forecast the financial consequences of new product introductions is very limited indeed.[23] This last conclusion is confirmed by the study by Edwin Mansfield and his colleagues of project selection in large US firms.[24] By comparing project forecasts with outcomes, Mansfield showed that managers find it difficult to pick technological and commercial winners:

- Probability of *technical* success of projects (*Pt*) = 0.80
- Subsequent probability of *commercial* success (Pc) = 0.20
- Combined probability for all stages: 0.8 × 0.2 = 0.16

He also found that managers and technical managers cannot predict accurately the *development costs*, *time periods*, *markets* and *profits* of R&D projects. On average, costs were greatly *underestimated*, and time periods *overestimated* by 140–280% in incremental product improvements, and by 350–600% in major new products. Other studies have found that:

- About half business R&D expenditures are on *failed* R&D projects. The higher rate of success in *expenditures* than in *projects* reflects the weeding out of unsuccessful projects at their early stages and before large-scale commercial commitments are made to them.[25]
- R&D scientists and engineers are often deliberately overoptimistic in their estimates, in order to give the illusion of a high rate of return to accountants and managers.[26]

Trying to get involved in the right projects is worth an effort, both to avoid wasting time and resources in meaningless activities, and to improve the chances of success. Project appraisal and evaluation aims to:

1. Profile and gain an overall understanding of potential projects.
2. Prioritize a given set of projects, and where necessary reject projects.
3. Monitor projects, e.g. by following up the criteria chosen when the project was selected.
4. Where necessary, terminate a project.
5. Evaluate the results of completed projects.
6. Review successful and unsuccessful projects to gain insights and improve future project management, i.e. learning.

Project evaluation usually assumes that there is a choice of projects to pursue, but where there is no choice project evaluation is still important to help to assess the opportunity costs and what might be expected from pursuing a project. Different situations and contexts demand different approaches to project evaluation. We argued earlier that complexity and uncertainty are two of the most important dimensions for assessing projects. Different types of project will demand specific techniques, or at least different criteria for assessment. A common method used is the risk assessment matrix.

A large number of techniques have been developed over the years, and are still being developed and used today. Most of these can be described by means of some common elements which form the core of any project evaluation technique:

- *Inputs* into the assessment include likely costs and benefits in financial terms, probability of technical and market success, market attractiveness, and the strategic importance to the organization.

- *Weighting*: as certain data may be given more relevance than other (e.g. of market inputs compared with technical factors), in order to reflect the company's strategy or the company's particular views. The data is then processed to arrive at the outcomes.
- *Balancing* a range of projects, as the relative value of a project with respect to other projects is an important factor in situations of competition for limited resources. Portfolio management techniques are specifically devoted to deal with this factor.

Economic and cost-benefit approaches are usually based on a combination of expected utility or Bayesian assumptions. Expected utility theory can take into account probabilistic estimates and subjective preferences, and therefore deals well with risk aversion, but in practice utility curves are almost impossible to construct and individual preferences are different and highly subjective. Bayesian probability is excellent at incorporating the effects of new information, as we discussed earlier under the diffusion of innovations, but is very sensitive to the choice of relevant inputs and the weights attached to these.

As a result no technique should be allowed to determine outcomes, as these decisions are a management responsibility. Many techniques used today are totally or partially software based, which have some additional benefits in automating the process. In any case, the most important issue, for any method, is the managers' interpretation.

There is no single 'best' technique. The extent to which different techniques for project evaluation can be used will depend upon the nature of the project, the information availability, the company's culture and several other factors. This is clear from the variety of techniques that are theoretically available and the extent to which they have been used in practice. In any case, no matter which technique is selected by a company, it should be implemented, and probably adapted, according to the particular needs of that organization. Most of the techniques in practical use incorporate a mixture of financial assessment and human judgement.

Perceptions of risk

Probability estimates are only the starting point of risk assessment. Such relatively objective criteria are usually significantly moderated by psychological (cognitive) perceptions and bias, or overwhelmed altogether by sociological factors, such as peer pressure and cultural context. Studies suggest that different people (and animals) have different perceptions and tolerances for risk taking. For example, a study comparing the behaviours of chimpanzees and bonobo apes found that the chimps were more prepared to gamble and take risks.[27] At first sight this appears to support the personality explanation for risk taking, but actually the two types of ape share more than 99% of their DNA. A more likely explanation is the very different environments in which they have evolved: in the chimp environment food is scarce and uncertain, but in the bonobo habitats food is plentiful. We are not suggesting that entrepreneurs are chimp-like, or accountants are ape-like, but rather that experience and context have a profound influence on the assessment of, and appetite for, risk.

At the individual, cognitive level, risk assessment is characterized by overconfidence, loss aversion and bias.[28] Overconfidence in our ability to make accurate assessments is a common failing, and results in unrealistic assumptions and uncritical assessment. Loss aversion is well documented in psychology, and essentially means that we tend to prefer to avoid loss rather than to risk gain. Finally, cognitive bias is widespread and has profound implications for the identification and assessment of risk. Cognitive bias results in us seeking and overemphasizing evidence which supports our beliefs and reinforces our bias, but at the same time leads us to avoid and undervalue any information which contradicts our view.[29] Therefore we need to be aware of and challenge our own biases, and encourage others to debate and critique our data, methods and decisions.

Studies of research and development confirm that measures of cognitive ability are associated with project performance. In particular, differences in reflection, reasoning, interpretation and sense making influence the quality of problem formulation, evaluation and solution, and therefore ultimately the performance of research and development. A common weakness is the oversimplification of problems characterized by complexity or uncertainty, and the simplification of problem framing and evaluation of alternatives.[30] This includes adopting a single prior hypothesis, selective use of information that supports this, and devaluing alternatives, and illusion of control and predictability. Similarly, marketing managers are likely to share similar cognitive maps, and make the same assumptions concerning the relative importance of different factors contributing to new product success, such as the degree of customer orientation versus competitor orientation, and the implications of relationship between these factors, such as the degree of inter-functional coordination.[31] So the evidence indicates the importance of cognitive processes at the senior management, functional, group and individual levels of an organization. More generally, problems of limited cognition include:[32]

- *Reasoning by analogy*, which oversimplifies complex problems.
- *Adopting a single, prior hypothesis bias*, even where information and trials suggest this is wrong.
- *Limited problem set*, the repeated use of a narrow problem-solving strategy.
- *Single outcome calculation*, which focuses on a simple single goal and a course of action to achieve it, and denying value trade-offs.
- *Illusion of control and predictability*, based on an overconfidence in the chosen strategy, a partial understanding of the problem and limited appreciation of the uncertainty of the environment.
- *Devaluation of alternatives*, emphasizing negative aspects of alternatives.

At the group or social level, other factors also influence our perception and response to risk. How managers assess and manage risk is also a social and political process. It is influenced by prior experience of risk, perceptions of capability, status and authority, and the confidence and ability to communicate with relevant people at the appropriate times.[33] In the context of managing innovation, risk is less about personal propensity for risk taking or rational assessments of probability, and more about the interaction of experience, authority and context. In practice managers deal with risk in different ways in different situations. General strategies include delaying or delegating decisions, or sharing risk and responsibilities. Generally, when managers are performing well, and achieving their targets, they have less incentive to take risks. Conversely, when under pressure to perform, managers will often accept higher risks, unless these threaten survival.

Politics of risk

In most organizations risk has become a negative term, something which should be minimized or avoided, and implies hazard or failure. This view, particularly common in the policy domain, is enshrined in the 'precautionary principle' and the many regulatory regimes it has spawned, which, as the title suggests, wherever possible promotes the avoidance of risk taking.[34]

However, this interpretation perverts the nature of risk and opportunity, which are central to successful innovation, and promotes inaction and the status quo, rather than improvement or change.

The term 'risk' is derived from the Latin 'to dare', but has become associated with hazard or danger. We must also consider the 'risk' of success, or risks associated with *not* changing.[35] Berglund provides a good working definition of risk in the context of innovation, as '*the pursuit of perceived opportunities under conditions of uncertainty*'.[36]

In a corporate context, he identifies three aspects of risk which need to be managed:

- Compliance with formal project and process requirements, rather than innovation outcomes.
- Internal control and autonomy, and influence and use of external expertise.
- Flexibility of the business model and experimentation with alternative configurations and organization.

In any large organization, there will be formal process and project requirements. However, these may conflict with the goals of innovation. Risk taking requires a degree of tolerance of uncertainty and ambiguity in the workplace. In the high risk-taking climate, bold new initiatives can be taken even when the outcomes are unknown. People feel that they can 'take a gamble' on some of their ideas. People will often 'go out on a limb' and be first to put an idea forward. In a risk-avoiding climate there is a cautious, hesitant mentality. People try to be on the 'safe side'. They decide 'to sleep on the matter'. They set up committees and they cover themselves in many ways before making a decision. When risk taking is too low, employees offer few new ideas or few ideas that are well outside of what is considered safe or ordinary. In risk-avoiding organizations people complain about boring, low-energy jobs and are frustrated by a long, tedious process used to get ideas to action. These conditions can be caused by the organization not valuing new ideas or having an evaluation system that is bureaucratic, or people being punished for 'drawing outside the lines'. It can be remedied by developing a company plan that would speed 'ideas to action'. When risk taking is too high you will see that people are confused. There are many ideas floating around, but few are sanctioned. People are frustrated because nothing is getting done. There are many loners doing their own thing in the organization and no evidence of teamwork. These conditions can be caused by individuals not feeling they need a consensus or buy-in from others on their team in their department or organization. A remedy might include some team building and improving the reward system to encourage cooperation rather than individualism or competition.[5]

A recent study of organizational innovation and performance confirms the need for this delicate balance between risk and stability. Risk taking is associated with a higher relative novelty of innovation (how different it was to what the organization had done before), and absolute novelty (how different it was to what any organization had done before), and that both types of novelty are correlated with financial and customer benefits.[37] However, the same study concludes that '*incremental, safe, widespread innovations may be better for internal considerations, but novel, disruptive innovations may be better for market considerations . . . absolute novelty benefits customers and quality of life, relative innovation benefits employee relations (but) risk is detrimental to employee relations*'. In fact, many of the critical risks which need to be identified and managed are internal to organizations, rather than the more obviously anticipated external risks such as markets, competition and regulation.[38] For example, at 3M, 100 years of successful innovation was almost reversed following a change of CEO and an emphasis on six-sigma quality processes, rather than maintaining an innovative climate and products.

The inherent uncertainty in some projects limits the ability of managers to predict the outcomes and benefits of projects. In such cases changes to project plans and goals are commonplace, being

TABLE 8.3 Management of conventional and risky projects

Conventional project management	Management of risky projects
Modest uncertainty	Major technical and market uncertainties
Emphasis on detailed planning	Emphasis on opportunistic risk taking
Negotiation and compromise	Autonomous behaviour
Corporate interests and rules	Individualistic and ad hoc
Homogeneous culture and experience	Heterogeneous backgrounds

driven by external factors, such as technological breakthroughs or changes in markets, as well as internal factors, such as changes in organizational goals. Together the impact of changes to project plans and goals can overwhelm the benefits of formal project planning and management (Table 8.3).[22]

This is consistent with the real options approach to investing in risky projects, because investments are sequential and managers have some influence on the timing, resourcing and continuation or abandonment of projects at different stages. By investing relatively small amounts in a wide range of projects, a greater range of opportunities can be explored. Once uncertainty has been reduced, only the most promising projects should be allowed to continue. For a given level of investment this real option approach should increase the value of the project portfolio. However, because decisions and the options they create interact, a decision regarding one project can affect the option value of another project.[39,40] Nonetheless, the real options perspective remains a useful way of conceptualizing risk, particularly at the portfolio level. The goal is not to calculate or optimize, but rather to help to identify risks and payoffs, key uncertainties, decision points and future opportunities that might be created.[41] Combined with other methods, such as decision trees, a real options approach can be particularly effective where high volatility demands flexibility, placing a premium on the certainty of information and timing of decisions.

8.5 Anticipating the resources

Given their mathematical skills, one might have expected R&D managers to be enthusiastic users of quantitative methods for allocating resources to innovative activities. The evidence suggests otherwise: practising R&D managers have been sceptical for a long time (see Box 8.2). An exhaustive report by practising European managers on R&D project evaluation classifies and assesses more than 100 methods of evaluation and presents 21 case studies on their use.[42] However, it concludes that no method can guarantee success, that no single approach to pre-evaluation meets all circumstances, and that – whichever method is used – the most important outcome of a properly structured evaluation

BOX 8.2

A chief executive officer's completely perfect and absolutely quantitative method of measuring his R&D programme.

I multiply your projects by words I can't pronounce,
And weigh your published papers to the nearest half an ounce;
I add a year-end bonus for research that's really pure,
(And if it's also useful, your job will be secure).

I integrate your patent-rate upon a monthly basis;
Compute just what your place in the race to conquer space is;
Your scientific stature I assay upon some scales
Whose final calibration is the Company net-to-sales.

And thus I create numbers where there were none before;
I have lots of facts and figures – and formulae galore –
And these quantitative studies make the whole thing crystal clear.
Our research should cost exactly what we've budgeted this year.

Source: R. Landon, cited in Dr A. Bueche (vice-president for Research and Development of the US General Electric Company) in From laboratory to commercial application: some critical issues. Paper presented at the *17th International Meeting of the Institute of Management Sciences*, London, 2 July 1970.

is improved communication. These conclusions reflect three of the characteristics of corporate investments in innovative activities:

1. They are uncertain, so that success cannot be assured.
2. They involve different stages that have different outputs that require different methods of evaluation.
3. Many of the variables in an evaluation cannot be reduced to a reliable set of figures to be plugged into a formula, but depend on expert judgements: hence the importance of communication, especially between the corporate functions concerned with R&D and related innovative activities, on the one hand, and with the allocation of financial resources, on the other.

Financial assessment of projects

As we showed earlier, financial methods are still the most commonly used method of assessing innovative projects, but usually in combination with other, often more qualitative approaches. The financial methods range from simple calculation of payback period or return on investment, to more complex assessments of net present value (NPV) through discounted cash flow (DCF).

Project appraisal by means of DCF is based on the concept that money today is worth more than money in the future. This is not because of the effect of inflation, but reflects the difference in potential investment earnings, that is the opportunity cost of the capital invested.

The NPV of a project is calculated using:

$$NPV = \Sigma_0^T P_t / (1 + i)^t - C$$

where:

P_t = Forecast cash flow in time period t
T = Project life
i = Expected rate of return on securities equivalent in risk to project being evaluated
C = Cost of project at time $t = 0$

In practice, rather than use this formula, it is easy to create standard NPV templates in a spreadsheet package such as Excel.

How to evaluate learning?

However, the potential benefits of innovative activities are twofold. First, *extra profits* derived from increased sales and/or higher prices for superior products, and from lower costs and/or increased sales from superior production processes. Conventional project appraisal methods can be used to compare the value of these benefits against their cost. Second, *accumulated firm-specific knowledge* ('learning', 'intangible assets') that may be useful for the development of *future* innovations (e.g. new uses for solar batteries, carbon fibre, robots, word processing). This type of benefit is relatively more important in R&D projects that are more long term, fundamental and speculative.

Conventional techniques cannot be used to assess this second type of benefit, because it is an 'option' – in other words, it creates the *opportunity* for the firm to invest in a potentially profitable investment, but the realization of the benefits still depends on a decision to commit further resources. Conventional project appraisal techniques cannot evaluate options (see Box 8.3).

The inherent uncertainty in most R&D projects limits the ability of managers to predict the outcomes and benefits of projects. Research suggests that changes to R&D plans and goals are common,

BOX 8.3

Why conventional financial evaluation methods do not work with investments in technology

The following text was written by the Professor of Finance at the Sloan School of Management at MIT.

> Suppose a firm invests in a negative *NPV* (net present value) project in order to establish a foothold in an attractive market. Thus a valuable second-stage investment is used to justify the immediate project. The second stage must depend on the first: if the firm could take the second project without having taken the first, then the future opportunity should have no impact on the immediate decision . . .
>
> At first glance, this may appear to be just another forecasting problem. Why not estimate cash flows for both stages, and use discounted cash flow to calculate the *NPV* for the two stages taken together?

You would not get the right answer. The second stage is an option, and conventional discounted cash flow does not value options properly. The second stage is an option because the firm is not committed to undertaking it. It will go ahead if the first stage works and the market is still attractive. If the first stage fails, or if the market sours, the firm can stop after stage 1 and cut its losses. Investing in stage 1 purchases an intangible asset: a call option on stage 2. If the option's present value offsets the first stage's negative *NPV*, the first stage is justified . . .

DCF (discounted cash flow) is readily applied to 'cash cows' – relatively safe businesses held for the cash they generate... It also works for 'engineering investments', such as machine replacements, where the main benefit is reduced cost in a defined activity.

DCF is less helpful in valuing businesses with substantial growth opportunities or intangible assets. In other words, it is not the whole answer when options account for a large fraction of a business's value.

DCF is no help at all for pure research and development. The value of R&D is almost all option value. Intangible assets' value is usually options value.

Myers, S. (1984) Finance theory and financial strategy. *Interfaces*, 14, 126–37.

being driven by external factors, such as technological breakthroughs, as well as internal factors, such as changes in the project goals. Together the impact of changes to project plans and goals overwhelm the effects of the quality of formal project planning and management.[22] This reality is consistent with the real options approach to investing in R&D, because investments are sequential and managers have some influence on the timing, resourcing and continuation or abandonment of projects at different stages. By investing relatively small amounts in a wide range of projects, a greater range of technological opportunities can be explored. Once uncertainty has been reduced, only the most promising projects are allowed to continue. For a given level of R&D investment this real option approach should increase the value of the project portfolio. However, because options interact, a decision regarding one project can affect the option value of another project (unlike NPV calculations, which rarely include interaction effects). Therefore the creation of further options through R&D projects may not increase the overall option value of the R&D portfolio, and conversely the interaction of options arising from different projects can give rise to a nonlinear increase in the combined option value.[39]

However, in almost all cases it is impossible to calculate the value of R&D using real options, because unlike financial options it is difficult to predict technological breakthroughs, estimate future sales from products flowing from the R&D (or project payoff), or to identify and model project-specific risks, and the time-varying volatilities of the processes and eventual values.[40] Nonetheless, the real options perspective remains a useful way of conceptualizing R&D investment, particularly at the portfolio level. It can help to make more explicit and to identify future growth options created by R&D, even when these are not related to the (current) goals of the R&D. Combined with decision trees, a real options approach can help to identify risks and payoffs, key uncertainties, decision points and future branches (options).[41] It is particularly effective where high volatility demands flexibility, placing a premium on the certainty of information and timing of decisions (see Research Note).

In other words, the successful allocation of resources to innovation depends less on robustness of decision-making techniques than on the organizational processes in which they are embedded.

RESEARCH NOTE The value of uncertainty

The real options approach has been used to evaluate R&D at both the project and firm levels. The idea is that investment in, or more strictly speaking spending on, R&D creates greater flexibility and a portfolio of options for future innovations, especially where the future is uncertain. Faced with uncertainty, managers can choose to commit additional resources to R&D to create an *option to grow*, or alternatively delay additional R&D to hold an *option to wait*.

This study examined the different and combined effects of market and technological uncertainty on the financial valuation of firms' investments in R&D. They examined the behaviour and performance of 290 firms over 10 years, and found that the relationship between R&D and firm valuation depended on the source and degree of uncertainty. They identify a U-shaped relationship between market uncertainty and R&D capital: increasing market uncertainty initially reduces the value of any unit of investment in R&D until a point of inflection, beyond which it augments the value. The higher the rate of market growth, the lower the point of inflection. Conversely, the relationship between technological uncertainty and R&D capital is an inverted U-shape. This suggests that investors put a limit on the value of technology hedging: at low levels of technological uncertainty there is limited value in creating options, and at very high levels the cost of maintaining many alternatives is too high.

Therefore it is important to identify the main sources of uncertainty, technology or market, in order to make better decisions about the potential value of investments in R&D options.

Source: Oriani, R. and M. Sobrero (2008) Uncertainty and the market value of R&D within a real options logic. *Strategic Management Journal*, 29, 343–61.

According to Mitchell and Hamilton,[43] there are three (overlapping) categories of innovation that large firms must finance. Each category has different objectives and criteria for selection, the implications of which are set out in Table 8.4.

1. *Knowledge building* – This is the early-stage and relatively inexpensive research for nurturing and maintaining expertise in fields that could lead to future opportunities or threats. It is often treated as a necessary overhead expense, and sometimes viewed with suspicion (and even incomprehension) by senior management obsessed with short-term financial returns and exploiting existing markets, rather than creating new ones.

   With knowledge-building projects, the central question for the company is: 'What are the potential costs and risks of not mastering or entering the field?' Thus, no successful large firm in manufacture can neglect to explore the implications of development in IT, even if IT is not a potential core competence. And no successful firm in pharmaceuticals could avoid exploring recent developments in biotechnology. Decisions about such projects should be taken solely by technical staff on the basis of technical judgements, and especially those staff concerned with the longer term. Market analysis should not play any role. Outside financial linkages are likely to be with academic and other specialist groups, and to take the form of a grant.
2. *Strategic positioning* – These activities are in between knowledge building and business investment, and an important – and often neglected – link between them. They involve applied R&D and feasibility

TABLE 8.4 **Resource allocation for different types of innovative project**

Objective	Technical activity	Evaluation criteria (% of all R&D)	Decision takers	Market analysis	Nature of risk	Higher volatility	Longer time horizons	Nature of external alliances
Knowledge building	Basic research, monitoring	Overhead cost allocation (2–10%)	R&D	None	Small = cost of R&D	Reflects wide potential	Increases search potential	Research grant
Strategic positioning	Focused applied research, exploratory development	'Options' evaluation (10–25%)	Chief executive R&D division	Broad	Small = cost of R&D	Reflects wide potential	Increases search potential	R&D contract, equity
Business Investment	Development and production engineering	'Net present value' analysis (70–99%)	Division	Specific	Large = total cost of launching	Uncertainty reduces net present value	Reduces present value	Joint venture Majority control

demonstration, in order to reduce technical uncertainties, and to build in-house competence, so that the company is capable of transforming technical competence into profitable investment. For this type of R&D, the appropriate question is: 'Is the project likely to create an option for a profitable investment at a later date?' Comparisons are sometimes made with financial stock options, where (for a relatively small sum) a firm can purchase the option to buy a stock at a specified price, before a specified date – in anticipation of increase in its value in future.

Decisions about this category of project should involve divisions, R&D directors and the chief executive, precisely because – as their description implies – these projects will help determine the strategic options open to the company at a later date. At this stage, market analysis should be broad (e.g. where could genetic engineering create new markets for vegetables in a food company?). A variety of evaluation methods may be used (e.g. the product–technology matrix), but they will be more judgemental than rigorously quantitative. Costs will be higher than those of knowledge building, but much lower than those of full-scale business investment. As with knowledge-building projects, both high volatility in predictions and expectations, and long time horizons, are not unwelcome signs of unacceptably high risk, but welcome signs are rich possibilities and sufficient time to explore them. Outside linkages require tighter management than those related to knowledge building, probably through a contract or equity participation.

3. *Business investment* – This is the development, production and marketing of new and better products, processes and services. It involves relatively large-scale expenditures, evaluated with conventional financial tools such as net present value. In such projects, the appropriate question is: 'What are the potential costs and benefits in continuing with the project?' Decisions should be taken at the level of the division bearing the costs and expecting the benefits. Success depends on meeting the precise requirements of specific groups of users, and therefore depends on careful and targeted marketing. Financial commitments are high, so that volatility in technological and market conditions is unwelcome, since it increases risk. Long time horizons are also financially unwelcome, since they increase the financial burden. Given the size and complexity of development and commercialization, external linkages need to be tightly controlled through majority ownership or a joint venture. Given the scale of resources involved, careful and close monitoring of progress against expectations is essential. For such projects most firms rely on financial methods to evaluate their project portfolio – around 77% of firms according to a recent survey. However, the same survey revealed that only 36% of the best performing firms rely on financial methods, compared to 39% which use strategic methods.[37] An explanation for the relatively poor performance of financial methods is that the sophistication of the models often far exceeds the quality of the data inputs, particularly at the early stages of a project's life.

Checklists are a commonly used example of a simple qualitative technique. A checklist is simply a list of factors which are considered important in making a decision in a specific case. These criteria include technical and commercial details, legal and financial factors, company targets and company strategy. Most useful criteria are essentially independent of the business field and the business strategy, but the precise criteria and their weights will differ in specific applications.

The requirements for the use of this technique are minimal, and the effort involved in using it is normally low. Another advantage of the technique is that it is very easily adaptable to the company's way of doing things. However, checklists can be a starting point for more sophisticated methods where the basic information can be used for better focus. One simple and useful example is a SWOT analysis, where projects are assessed for their strengths, weaknesses, opportunities and threats.

Therefore, this technique can be developed further and the analysis interaction and feedback can be easily managed using simple information technology. Ways to make the technique more sophisticated include:

- To include some quantitative factors among the whole list of factors.
- To assign different weights to different factors.
- To develop a systematic way of arriving at an overall opinion on the project, such as a score or index.

A simple checklist could be one made up of a range of factors which have been formed to affect the success of a project and which need to be considered at the outset. In the evaluation procedure a project is evaluated against each of these factors using a linear scale, usually 1 to 5 or 1 to 10. The factors can be weighted to indicate their relative importance to the organization.

The value in this technique lies in its simplicity, but by the appropriate choice of factors it is possible to ensure that the questions address, and are answered by, all functional areas. When used effectively this guarantees a useful discussion, an identification and clarification of areas of disagreement and a stronger commitment, by all involved, to the ultimate outcome. Table 8.5 shows an example of a checklist, developed by the Industrial Research Institute, which can be adapted to almost any type of project.

TABLE 8.5 List of potential factors for project evaluation

	Score (1-5)	Weight (%)	S × W
Corporate objectives			
Fits into the overall objectives and strategy			
Corporate image			
Marketing and distribution			
Size of potential market			
Capability to market product			
Market trend and growth			
Customer acceptance			
Relationship with existing markets			
Market share			
Market risk during development period			
Pricing trend, proprietary problem, etc.			

(continued)

TABLE 8.5 **(Continued)**

	Score (1-5)	Weight (%)	S × W
Complete product line			
Quality improvement			
Timing of introduction of new product			
Expected product sales life			
Manufacturing			
Cost savings			
Capability of manufacturing product			
Facility and equipment requirements			
Availability of raw material			
Manufacturing safety			
Research and development			
Likelihood of technical success			
Cost			
Development time			
Capability of available skills			
Availability of R&D resources			
Availability of R&D facilities			
Patent status			
Compatibility with other projects			
Regulatory and legal factors			
Potential product liability			

(continued)

TABLE 8.5 **(Continued)**

	Score (1-5)	Weight (%)	S × W
Regulatory clearance			
Financial			
Profitability			
Capital investment required			
Annual (or unit) cost			
Rate of return on investment			
Unit price			
Payout period			
Utilization of assets, cost reduction and cash-flow			

As with all techniques, there is a danger that project appraisal becomes a routine that a project has to suffer, rather than an aid to designing and selecting appropriate projects (Box 8.4). If this happens people may fail to apply the techniques with the rigour and honesty required, and can waste time and energy trying to 'cheat' the system. Care needs to be taken to communicate the reasons behind the methods and criteria used, and where necessary these should be adapted to different types of project and to changes in the environment.[44]

BOX 8.4 **Limitations of conventional project and product assessment**

Clayton Christensen and colleagues argue that three commonly used means of assessment discourage expenditure on innovation. Firstly, conventional means of assessing projects, such as discounted cash flow (DCF) and the treatment of fixed costs, favour the incremental exploitation of existing assets, rather than the more risky development of new capabilities. Secondly, methods such as the stage-gate process demand data on estimated markets, revenues and costs, which are much more difficult to generate for more radical innovations. Finally, senior managers and publically quoted firms are typically assessed by improvements in the earning per share (EPS), which encourages short-term investments and returns – most institutional investors hold shares for only 10 months in the USA, and the tenure of CEOs is shrinking.

Whilst they appreciate the benefits of such financial methods of assessment, they argue that such techniques should be adjusted to redress the balance for risk taking and expenditure on innovation. For example, when using DCF, comparative assessments should be made with the option of doing nothing, or not investing in an innovative project, rather than assuming a decision not to invest will result in no loss of competitiveness. Similarly, for the stage-gate process, they propose focusing less on the (unreliable) quantitative forecasts, and much more on challenging and testing the assumptions made in business planning. Finally, they believe that the use of short-term measures such as EPS is no longer appropriate because they provide perverse incentives. The original rationale for this type of approach was the principal–agent problem – to try to align the interests of the principals (owners/shareholders) and their agents (managers). However, the growth of collective institutional ownership of most public firms has created an agent–agent problem, and the interests of the agents need to be more aligned to promote innovation.

Source: Christensen, C.M, S.P. Kaufmann and W.C. Shih (2008) Innovation killers: how financial tools destroy your capacity to do new things. *Harvard Business Review*, January, 98–105.

Portfolio methods try to deal with the issue of reviewing across a set of projects and look for a balance of economic and non-financial risk/reward factors (Case study 8.1). A typical example is to construct some form of matrix measuring risk vs. reward, for example, on a 'costs of doing the project' vs. expected returns (Figure 8.3).

Rather than reviewing projects just on these two criteria it is possible to construct multiple charts to develop an overall picture, for example, comparing the relative familiarity of the market or technology – this would highlight the balance between projects that are in unexplored territory as opposed to those in familiar technical or market areas (and thus with a lower risk). Other possible axes include ease of entry vs. market attractiveness (size or growth rate), the competitive position of the organization in the project area vs. the attractiveness of the market or the expected time to reach the market vs. the attractiveness of the market. Some examples of portfolio management tools are given on the website.

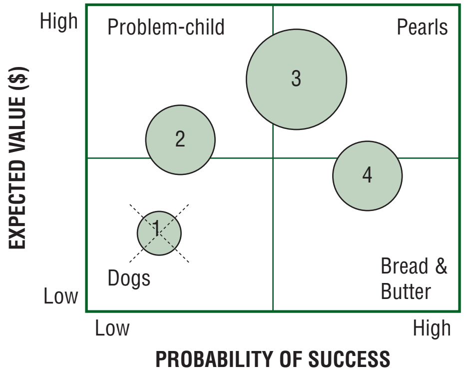


FIGURE 8.3: An example matrix-based portfolio

CASE STUDY 8.1

The Arthur D. Little matrix for technology decisions

A number of tools have been developed to help with strategic decision making around technology investments . Typical of these are those which make some classification of technologies in terms of their open availability and the ease with which they can be protected and deployed to strategic advantage. For example, the consultancy Arthur D. Little uses a matrix which groups technological knowledge into four key groups – base, key, emerging and pacing.

- Base technologies represent those on which product/service innovations are based and which are vital to the business. However they are also widely known about and deployed by competitors and offer little potential competitive advantage.
- Key technologies represent those which form the core of current products/services or processes and which have a high competitive impact – they are strategically important to the organization and may well be protectable through patent or other form.
- Pacing technologies are those which are at the leading edge of the current competitive game and may be under experimentation by competitors – they have high but as yet unfulfilled competitive potential.
- Emerging technologies are those which are at the technological frontier, still under development and whose impact is promising but not yet clear.

Making this distinction helps identify a strategy for acquisition based on the degree of potential impact plus the importance to the enterprise plus the protectability of the knowledge. For base technologies it may make sense to source outside whereas for key technologies an in-house or carefully selected strategic alliance may make more sense in order to preserve the potential competitive advantage. Emerging technologies may be best served by a watching strategy, perhaps through some pilot project links with universities or technological institutes.

Models of this can be refined, for example, by adding to the matrix information about different markets and their rate of growth or decline. A fast-growing new market may require extensive investment in the pacing technology in order to be able to build on the opportunities being created whereas a mature or declining market may be better served by a strategy which uses base technology to help preserve a position but at low cost.

For more detail on this approach see http://www.adlittle.com/.

A useful variant on this set of portfolio methods is the 'bubble chart' in which the different projects are plotted but represented by 'bubbles' – circles whose diameter varies with the size of the project (for example in terms of costs). This approach gives a quick visual overview of the balance of different-sized projects against risk and reward criteria. Case study 8.2 gives an example. However it is important to recognize that even advanced and powerful screening tools will only work if the corporate will is present to implement the recommended decisions, for example, Cooper and Kleinschmidt found that the majority of firms studied (885) performed poorly at this stage, and often failed to kill off weak concepts.[45]

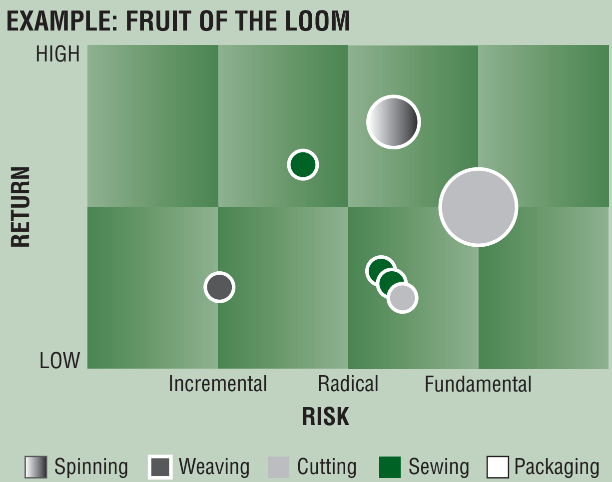
CASE STUDY 8.2

Portfolio management of process innovation in Fruit of the Loom

The clothing manufacturer Fruit of the Loom reviewed its worldwide process innovation activities using a portfolio framework to help provide a clearer overview and develop focus. It used simple categories:

- 'Incremental' – essentially continuous improvement projects
- 'Radical' – using the same basic technology but with more advanced implementation
- 'Fundamental' – using different technology, for example, laser cutting instead of mechanical

Plotting on to a simple colour-coded bubble chart enabled a quick and easily communicable overview of their strategic innovation portfolio in this aspect of innovation.



Source: Oke, private communication, 2003.

How practising managers cope

These two sets of difficulties – in evaluating the potential contributions of technological investments to firm-specific intangible assets, and in dealing with uncertainty – are reflected in how successful managers allocate resources to technological activities. In particular, they:

- Encourage *incrementalism* – step-by-step modification of objectives and resources, in the light of new evidence.
- Use *simple rules* models for allocating resources, so that the implications of changes can be easily understood.
- Make explicit from the outset criteria for *stopping* the project or programme.

- Use *sensitivity analysis* to explore if the outcome of the project is 'robust' (unchanging) to a range of different assumptions (e.g. 'What if the project costs twice as much, and takes twice as long, as the present estimates?').
- Seek the reduction of *key uncertainties* (technical and – if possible – market) before any irreversible commitment to full-scale – and costly – commercialization.
- Recognize that *different types* of innovation should be evaluated by *different criteria*.

VIEWS FROM THE FRONT LINE

Justifying value in R&D

A constant battle is being fought by R&D centres to obtain funds or prove that what they do receive is creating value for the company.

There are three distinct types of project defined by their anticipated duration before they contribute returns to a business:

1. Short term – incremental improvements to existing products.
2. Intermediate – substantial alterations or significant updates on well-founded products and markets.
3. Long term – speculative projects on something that may have a big future.

In our business of building power stations our products last for 40–50 years (with intermittent overhaul and servicing). Therefore, for us short term is 1–3 years, intermediate 3–7 years and long term can be over 20 years.

1. *Short term* – these are small continuous improvements or cost reduction projects. Each on its own is easy to cost but the return is difficult to quantify, e.g. improving a $10 wiper blade on a car is easy to define, but how many more cars do you sell as a result 1, 10, 100, 100 000 or zero? However, over time if these small changes are not made the car will become undesirable and thus less saleable compared to the competition.

   This is more difficult when the concept of fashion is introduced as this is more emotive than a relatively easy measurable such as an increase in performance.

   The motoring industry over time has become full of minor improvements that are now regarded as essential – heaters, radio, electric windows and door mirrors, seats, air conditioning, satellite navigation, cruise control, iPod connections etc.
2. *Intermediate* – are the easiest to quantify and define as they are ringfenced projects for a known product in a relatively stable and an understood market.

   An example could be the moves from records, cassettes, CDs or video, DVD to Blu-ray HD. The demand from the market is fairly easy to quantify and one generation has more or less substituted the previous one. The technology has been uncertain but understood. These types of projects can be compared and 'valued' via traditional evaluation tools such as NPV or option pricing.

In the power business such technologies would now encompass wind turbines and even nuclear power.

3. *Long term* – and sometimes very disruptive technologies and products. PCs and mobile communications are two such recent products.

   The costs and time to market were long and adoption too was a drawn out affair. Costs of development were extremely hard to predict but the return was potentially enormous but equally hard to predict (see, for example, Microsoft and Vodafone).

   Which companies could have run a NPV on these, how did Sony Walkman and iPod pass the financial hurdles, when both were new breakthroughs?

   In the power business we are struggling with 'proving' the returns for Carbon Capture and Storage – with 10–20 year predictions for the development of the technology let alone commercialization versus the trillions of potential value – the race is on, but the NPV does not look realistic.

   So where does that leave the R&D director? It's going to cost a lot, over an unknown duration (I don't know how we will invent the future) but it will be a massive market – trust me . . .

   The best we can presently do is portfolio management – borrowed from the financial markets which basically translate as 'don't put all your eggs in one basket' – because we don't know what the future holds.

Source: Richard Dennis, Director R&D, Doosan-Babcock

Summary and further reading

The process of innovation is much more complex than technology responding to market signals. Effective business planning under conditions of uncertainty demands a thorough understanding and management of the dynamics of innovation, including conception, development, adoption and diffusion.

The adoption and diffusion of an innovation depend on the characteristics of the innovation, the nature of potential adopters and the process of communication. The relative advantage, compatibility, complexity, trialability and observability of an innovation all affect the rate of diffusion. The skills, psychology, social context and infrastructure of adopters also affect adoption. Epidemic models assume that innovations spread by communication between adopters, but bandwagons do not require this. Instead, early adopters influence the development of an innovation, but subsequent adopters may be more influenced by competitive and peer pressures. Forecasting the development and adoption of innovations is difficult, but participative methods such as Delphi and scenario planning are highly relevant to innovation and sustainability. In such cases the process of forecasting, including consultation and debate, is probably more important than the precise outcomes of the exercise.

More generally, the problems of forecasting the future development, adoption and diffusion of innovations are dealt with by many authors in the innovation field. Everett Roger's classic text the *Diffusion of Innovations*, first published in 1962, remains the best overview of this subject, the most recent and updated edition being published in 2003 (Simon and Schuster). More up-to-date accounts can be found in *Determinants of Innovative Behaviour*, edited by Cees van Beers, Alfred