Chapter 2

Types of Innovation

LEARNING OBJECTIVES

When you have completed this chapter you will be able to:

- Distinguish the different forms that innovation can take, such as product, process and service innovation
- Differentiate and distinguish between the different types of innovation, such as radical and incremental innovation
- Describe each type of innovation
- Analyse different types of innovation in terms of their impact on human behaviour, business activity and society as a whole.

INTRODUCTION

The notion that innovation is essentially about the commercialisation of ideas and inventions suggests that it is relatively straightforward and simple. Far from it, not only is the step from invention to commercially successful innovation often a large one that takes much effort and time, innovations can and do vary enormously. In addition the term 'innovation' is widely used, probably because it frequently has very positive associations, and is often applied to things that really have little to do with innovation, certainly in the sense of technological innovation. The purpose of this

chapter is to try and produce some sort of order from the apparent chaos and confusion surrounding innovation.

MAKING SENSE OF INNOVATION

If innovation comes in a variety of shapes and sizes and is used by different people to mean different things then making coherent sense of the subject is not an easy task. Grouping innovations into categories can help. Essentially by putting innovations in groups it should make it easier to make sense of innovation as a whole simply because one can then take each group in turn and subject it to detailed scrutiny. If it is easier to make sense of a small group than large one then we should be on the way to making sense of innovation.

Two kinds of categorization are attempted. The first centres on different forms of innovation. Form in the sense in which the term is used here applies to the use or application of the innovation. Three applications are considered: product, service and process innovations.

The second categorization is based on the degree of novelty associated with the innovation. It implies that there are different degrees of novelty associated with innovation. As a result, one sometimes finds that things described as innovations actually involve little or no novelty. Take the case of a new wrapper for a chocolate bar. For the people marketing the product, the new wrapper may well appear to be a significant innovation, hence justifying the use of words like innovation and innovative in promotional campaigns. But the reality is that if the same type of

wrapper is already in use on other similar products there really is very little innovation. On the other hand one can have innovations such as television, developed by John Logie Baird, which not only transformed the nature of leisure time, created a new creative industry and provided employment for thousands, but also went on to transform a whole host of other aspects of our society including politics, advertising, the provision of information and sport. Recognising different degrees of novelty, this categorization considers four types: radical, architectural, modular and incremental.

FORMS OF INNOVATION

This categorization is based on the idea of applications or uses for innovation. By this we mean areas or fields where innovations are used. It is possible to differentiate three principal applications for innovation: products, services and processes.

Product Innovation

Product innovations loom large in the public imagination. Products, especially consumer products are probably the most obvious innovation application. The Dyson bagless vacuum cleaner is an example of a product innovation. James Dyson developed what he terms ‘dual cyclone’ technology (Dyson, 1997) and used it to create a new more efficient vacuum cleaner. As a vacuum cleaner it is a consumer product and what makes it an innovation, i.e. what is ‘innovative’ about it, is that it functions in a quite different way from a conventional vacuum cleaner. It is still a vacuum cleaner and it does what vacuum cleaners have always done, it extracts dust and other items of household debris from carpets and upholstery. But the innovation

lies in the way in which it functions. Instead of employing a fan to suck dust into a bag, it dispenses with the bag and uses Dyson's patented 'dual cyclone' technology to extract dust and place it in a clear plastic container. It is a nice example of a product innovation because it is an everyday household product where you can actually see the innovation at work, a fact that James Dyson, an experienced industrial designer and entrepreneur, no doubt had in mind when he designed his first bagless vacuum cleaner, the Dyson 001.

From a commercial perspective the attraction of product innovations is that the novelty of a new product will persuade consumers to make a purchase. It is no surprise that 'new product development' is one of the four business strategies put forward by Ansoff for the future development of a business. Of course product innovations don't have to be consumer products, they can just as easily be industrial products such as machinery and equipment.

Service Innovations

Often overlooked but equally important are service innovations, that take the form of new service applications. One reason why service innovations don't attract as much attention as product innovations is that they are often less spectacular and less eye-catching. This probably has something to do with the fact that where innovation is concerned, the public imagination has always tended to identify with inventions, rather than innovation as such. Because of their high novelty value, inventions are usually products.

Service innovations typically take the form of a new way of providing a service, often with a novel and very different business model. Occasionally they even take the form of an entirely new service. The creation of the 'Direct Line' telephone insurance business is a good example of the first type of service innovation. For years the insurance business had been transacted via high street outlets, door-to-door, by post or through intermediaries known as insurance brokers. Peter Wood, the creator of the Direct Line telephone insurance business, realised that with appropriate on line computer services, it would be possible to cut out these expensive and unproductive ways of dealing with the public and deal direct with the customer via the telephone. Developments in computing and telecommunications in recent years have given rise to a whole raft of service innovations very similar to Direct line where new technologies are used both to provide customers with a better service and to enable service providers to improve their productivity by providing it more cheaply.

MINI-CASE: SOUTH WEST AIRLINES

Founded in the late 1960s by Herb Kellner, it was South West Airlines that started the 'no frills' revolution in air travel.

In Europe in the last 10 years air travel has been transformed by the introduction of low cost services offered by 'no frills' carriers. The innovation which these carriers introduced has been the provision of easily accessible scheduled short haul services at fares very much lower than those offered by conventional scheduled airlines. The result has been an enormous increase in both numbers travelling by air and the range of destinations served.

Yet this was not a European innovation. The pioneer of low cost 'no frills' air transport was South West Airlines based in Texas. Under its charismatic founder, Herb Kellner, South West Airlines had to fight legal battles with local competitors for the first four years of existence just to be allowed to fly. Competitors argued there simply wasn't enough business to warrant another airline in the region. When it did finally get airborne it was faced with a price war with Braniff and other airlines as they tried to drive it out of business.

Based at Love Field in downtown Dallas South West Airlines was able to survive by offering customers a very different package from conventional airlines. The package included low fares (usually 60% below conventional airlines), high frequencies, excellent on-time departure rates and direct sales (i.e. no travel agents). What was not being offered was meals, pre-assigned seats, different classes of seating and connecting flights. This was achieved by means of: a single aircraft type (then and now the Boeing 737), smaller low cost airports, rapid turnarounds (typically 15-20 minutes), high load factors, and point-to-point services (Procter, 1994).

The 'no frills' service package diverted some traffic away from existing carriers but more significantly it generated a lot of new business, especially leisure and business passengers who could be persuaded to fly rather than drive. As Herb Kellner (Dogannis, 2001: p128) put it,

> *'we are not competing with airlines, we're competing with ground transportation.'*

De-regulation of airline services in the US in 1978 meant that South West Airlines was well placed to expand in Texas with this innovation in airline service. Traffic growth proved well above average. South West was able to expand by adding more capacity to its fleet, but instead of adding routes as airlines normally did Kellner's strategy was to increase flight frequency on existing routes.

It worked. Today South West Airlines is the fifth biggest carrier in the US, and is the most consistently profitable airline in the country. Yet it has stuck to its innovative business model. Not only that, but the model has been copied with great success in Europe, first by Ryannair (Dogannis, 2001) and then by a host of other airlines including EasyJet and BMI Baby to create a low cost revolution in air travel across the continent.

Source: Procter (1994)

Sometimes one gets innovations that take the form of completely new services. Ebay, the internet auction, and Lastminute.com the clearing house for late bookings on anything from holidays to gifts, would probably come under this heading. So too would Federal Express the brainchild of Frederick W. Smith. Operating in an established industry: parcel delivery, Smith pioneered the idea of overnight delivery using a hub and spoke system (Nayak and Ketteringham, 1993). During the day trucks collect parcels and bring them to an airport where they are sorted and then flown overnight to a hub near their destination ready for delivery the next day.

Process Innovations

If service innovations come second behind product innovations, then process innovations almost certainly come a poor third. And yet process innovations often have an even bigger impact on society than either product or service innovations. The early nineteenth century *Luddite* movement in and around Nottingham(Chapman, 2002), where stocking knitters who worked on machines in the home, took to rioting and breaking the new more efficient machines located in factories, because they feared that the new machines would destroy their livelihoods, is testimony to the power of process innovations.

Although generally less well known than product innovations, examples of process innovations, including ones that have had a dramatic impact on society as a whole, abound.

The humble photocopier, developed by Chester Carlson, may not sound like a spectacular innovation, and yet it had a big impact on the way in which administrative systems in offices are organised. One has only to look at what happens in an office when the photocopier breaks down to see how reliant we are upon it.

Much less well known, but just as significant in terms of its impact on society, is the *Float Glass* process developed by Alistair Pilkington, in which plate glass is manufactured by drawing glass out across a bed of molten tin (Quinn, 1991). Prior to the introduction of this process innovation, plate glass used for shop windows and office windows was expensive and of poor quality largely because the only way of

getting a flat surface was to grind it and polish it. The *Float Glass* process at a stroke eliminated the need for time consuming grinding and polishing it, leading to a dramatic fall in costs. Architects and property developers could now afford to specify large sheets of plate glass when constructing new buildings, where in the past they would have been prevented because of the cost. The result can be seen in the public buildings constructed in the last thirty years, where everything from office blocks and hotels to airports and shopping malls now employ large expanses of glass.

Table 2.1: Craft v. Mass Production at Ford 1913-1914

Assembly time	*Craft Production, 1913, (*minutes)	*Mass Production, 1914, (*minutes)	*Reduction in effort*
Engine	594	226	62%
Magneto	20	5	75%
Axle	150	26.5	83%
Components into vehicle	750	93	88%

Source: Womack, Jones and Roos (1990)

Nor is it only process innovations that affect working practices and the physical infrastructure of towns and cities. Process innovations often have a big impact on the economics of production. As table 2.1 shows, Henry Ford's introduction of the moving assembly line at his new Highland Park plant in Detroit in 1913 resulted in a dramatic reduction in manufacturing effort. Improved productivity on this scale, enabled him to dramatically reduce the price of his Model T car. The price of a Ford

Model T which in 1908 was $850, fell to $600 in 1913 and $360 by 1916 (Freeman and Louçã, 2001: p275). As Ford reduced his prices, demand took off and the car, which had hitherto been an ostentatious toy only available to a small wealthy elite, was opened to a broad cross-section of society.

Today a similar revolution in production is taking place, but this time the revolution is occurring not on the factory floor but in the office. Business-to-business (B2B) E-commerce is dramatically reducing the need for paperwork and those who process paper, namely administrators. It is no surprise that all sorts of business organisations from airlines to insurance companies offer a discount for buying online. Buying online means less paper and money spent processing paper. One has only to look at the size of the discounts offered to get an idea of the efficiency gains that firms can make.

Table 2.2: Forms of Innovation

Form	**Innovation**	**Innovator**	**Country**
Product	Walkman	Akio Morita/Sony	Japan
	Ballpoint Pen	Laszlo Biro	Hungary
	Television	John Logie Baird	UK
	Spreadsheet	Dan Bricklin	USA
Service	Telephone Insurance	Peter Wood/RBS	UK
	Credit Card	R. Schneider/F. McNamara	USA
	Internet Bookstore	Jeff Buzos	USA
	"No Frills" Airline	Herb Kelleher/ Rollin King	USA

Process	Moving Assembly Line	Henry Ford	USA
	Float Glass	Alistair Pilkington	UK
	Single Minute Exchange of Dies (SMED)	Shigeo Shingo/Toyota	Japan
	Computerised Airline Reservations (SABRE)	IBM/American Airlines	USA

TYPES OF INNOVATION

It has long been noted that one can differentiate innovations in terms of the degree of novelty associated with them. Some innovations employ a high degree of novelty, while others involve little more than 'cosmetic' changes to an existing design. This distinction between big change and small changes innovations has led some to group innovations as either radical or incremental (Freeman, 1982). However differentiating innovations using just two classes in this way is rather limited and does not bring out the subtle but important differences between innovations. In particular it fails to show where the novelty often lies. To cater for this Henderson and Clark (1990) use a more sophisticated analysis. Their analysis incorporates both radical and incremental innovation but within a more wide-ranging analysis that is both robust and meaningful. Henderson and Clark's (1990) analytical framework provides a typology that allows us to analyse more modest innovations and at the same time predict their impact in terms of both competition and the marketplace. Although this typology focuses primarily on product innovations it can equally be applied to service and process innovations.

At the heart of Henderson and Clark's analytical framework is the recognition that products are actually systems. As systems they are made up of components that fit together in a particular way in order to carry out a given function.

Example

Pen = *knib + ink storage + stem + cover + ink*

System = *interaction of components*

Henderson and Clark (1990) point out that to make a product normally requires two distinct types of knowledge:

- Component knowledge

  i.e. knowledge of each of the components that performs a well defined function within a broader system that makes up the product. This knowledge forms part of the 'core design concepts' (Henderson and Clark, 1990) embedded in the compoents.

- System knowledge

  i.e. knowledge about the way the components are integrated and linked together. This is knowledge about how the system works and how the various components are configured and work together. Henderson and Clark (1990) refer to this as architectural knowledge.

MINI-CASE: AUTOMATIC WASHING MACHINE

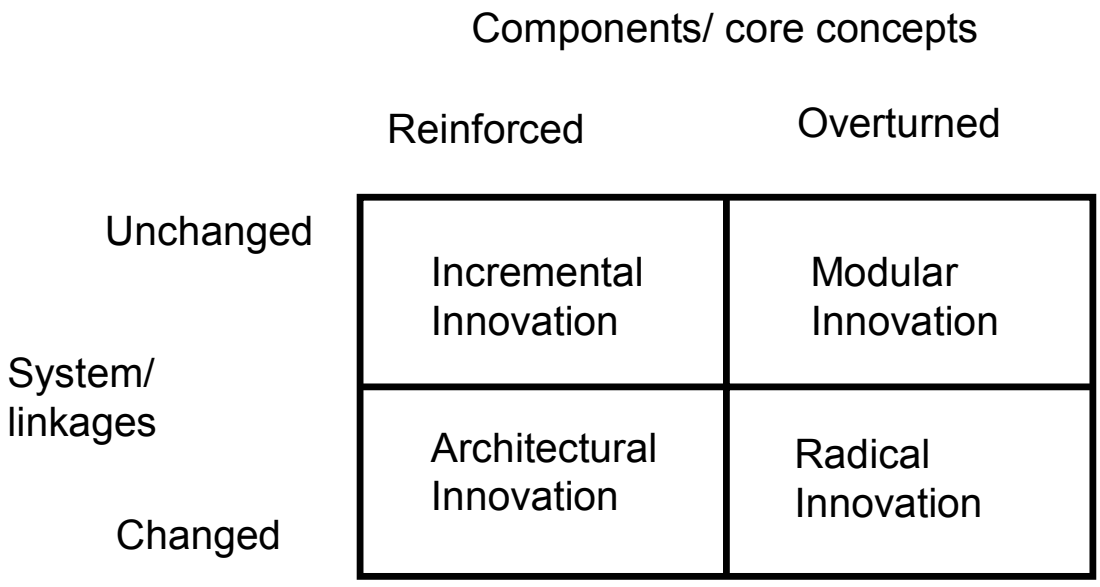
The modern automatic washing machine has been subjected to a variety of types of innovation. The washing machine is a system for washing for clothes. The components comprise: motor, pump, drum, programmer, chassis, door and body. These components are linked together into an overall system. Component knowledge is the knowledge that relates to each of the components. System knowledge on the other hand is about the way in which the components interact. The interaction is determined by the way in which the system is configured. Responsible for the design and development of the system, washing machine manufacturers frequently buy-in component knowledge by buying components and then assembling them into a finished product.

Washing machines have been affected by both incremental and architectural innovation. Changes in the spin speed are an example of incremental innovation. The spin speed determines how dry the clothes will be when they come out of the machine. 20 years ago the fastest machines spun at up to about 1,000rpm. Gradually spin speeds have risen and today the fastest machines spin at 1,600rpm. Although these advances have resulted in improved performance, the system has remained unchanged. However there have been architectural innovations in the washing machine field. In the 1960s most washing machines were 'twin tubs', where the washer and the spinner were completely separate and placed alongside each other with access via the top of the machine. Clothes had to be manually moved from the washer into the spinner. The automatic washing machine with the washer and spinner

combined in a single drum, allowing all the operations to be completed in a single cycle, was an architectural innovation. Similarly when Dyson launched its Contrarotator™ washing machine in November 2000 this was another architectural innovation. This has not just one drum, as on a conventional machine, but two that rotate in opposite directions. This change in the configuration of the system gives an entirely different washing system.

Henderson and Clark (1990) use the distinction between component and system knowledge to differentiate four categories or types of innovation. They use a two dimensional matrix. On one axis are component changes on the other are linkage (i.e. system) changes:

Figure 2.1: Typology of Innovations



Source: Henderson and Clark (1990)

In this analysis Incremental and Radical innovation are polarised as being at opposite extremes. However the analysis introduces two intermediate stages between these two extremes: Modular innovation and Architectural innovation:

Table 2.3: Changes associated with Types of Innovation

Innovation	Components	System
Incremental	Improved	No change
Modular	New	No change
Architectural	Improved	New configuration/architecture
Radical	New	New configuration/architecture

Incremental Innovation

Incremental innovation refines and improves an existing design, through improvements in the components. However it is important to stress these are improvements not changes, the components are not radically altered. Christensen (1997) defines incremental innovation in terms of:

> *'a change that builds on a firm's expertise in component technology within an established architecture.'*

In the case of the washing machine example used earlier, incremental innovation would be case of offering a machine with a more powerful motor to give faster spin speeds.

Incremental innovations are the commonest. Gradual improvements in knowledge and materials lead to most products and services being enhanced over time. However these enhancements typically take the form of refinements in components rather than changes in the system. Thus a new model of an existing and established product (perhaps described as a 'mark 2' version) is likely to leave the architecture of the system unchanged and instead involve refinements to particular components. With the system and the linkages between components unchanged and the design of the components reinforced (through refinements and performance improvements) this places such innovations in the top left hand quadrant of figure 2.1, where they are designated incremental innovations.

Radical Innovation

Radical innovation is about much more than improvements to existing designs. A radical innovation calls for a whole new design, ideally using new components configured (i.e. integrated into the design) in a new way. In Henderson and Clark's (1990) terms,

> *'Radical innovation establishes a new dominant design, and hence a new set of core design concepts embodied in components that are linked together in a new architecture.'*

Radical innovations are comparatively rare. Rothwell and Gardner (1989) estimated that at the most about 10 per cent of innovations are radical. Radical innovation is often associated with the introduction of a new technology. In some cases this will be a transforming technology, perhaps even one associated with the transforming effect of a Kondratiev long wave.

Table 2.4: Radical Innovations

Radical Innovation	**Technology**	**Impact on Society**
Telephone	Telecommunications	New means of mass communication
Jet Airliner	Jet power	Growth of mass travel, foreign holidays
Television	Television	New leisure activity, entertainment
Personal Computer	Microprocessor	New administrative system, Internet services e.g. banking

In terms of Henderson and Clark's framework radical innovation is located in the bottom right hand quadrant, at the opposite extreme from incremental innovation, as it involves both new components and a new design with a new architecture that links the components together in a different way.

MINI-CASE: NEVER ASK PERMISSION TO INNOVATE

In 1956, a small American company invented a device called the 'Hush-a-Phone'. It was a plastic cup designed to be attached to the microphone end of a telephone

handset in order to facilitate telephone conversations in noisy environments - rather like cupping your hand over the phone.

When Hush-a-Phone appeared on the market, AT&T – then the monopolistic supplier of telephone services to the US public – objected, on the grounds that it was a crime to attach to the phone system any device not expressly approved by AT&T. Hush-a-Phone had not been thus approved. The Federal Communications Commission agreed with AT&T. The fact that the device in no way 'connected' with the network was neither here nor there. Hush-a-Phone was history.

A few years later, when Paul Baran proposed the packet-switching technology which eventually under-pinned the internet, AT&T first derided and then blocked its development. One of AT&T's executives eventually said to Baran: 'First, it can't possibly work, and if it did, damned if we are going to allow the creation of a competitor to ourselves.'

Note the verb 'allow'. In a single word it explains why we should never permit the established order to be gatekeepers of innovation.

This is not widely understood by legislatures or governments, and it is particularly not understood by our own dear DTI (aka the Department of Torpor and Indolence), which thinks that the way to encourage innovation is to get all the established players in an industry together and exhort them to do it.

Innovation comes in two forms. The first is incremental – the process of making regular improvements to existing products and services. This is a cosy, familiar business which is easily accommodated by the established industrial order and by its regulatory bodies. It is what governments and corporations have in mind when they declare they are in favour of innovation.

The second kind of innovation is the disruptive variety – defined as developments that upset, supersede or transform established business models, user expectations and government frameworks and create hitherto unimagined possibilities. In other words, change that upsets powerful apple-carts.

This is the kind of innovation that the established order really fears – and often tries hard to squash. And yet, if our societies and economies are to remain vibrant, it is the only kind of innovation that matters. We are thus faced with a dilemma: on the one hand, we need disruptive innovation; on the other, the established order will never make it happen. So what do we do?

This is the central policy issue confronting every modern government. Yet the answer – as a striking new pamphlet by Demos argues – is staring us in the face it involves learning from the history of the internet. The reason it spurred such an explosion of disruptive change is that it was an ***innovation commons*** *– an uncontrolled space equally available to all. A whole raft of powerful technologies – for example, the world wide web, streaming audio, video conferencing, internet telephony, instant messaging, peer-to-peer networking, interactive gaming, online auctions, chat – came into being because their inventors had unfettered access to the network. They didn't*

have to ask the permission of AT&T or BT or the DTI to implement their ideas. If the invention was good enough, then it could, and did, conquer the world.

The lesson for the UK – and particularly Ofcom, the new omnipotent communications regulator – is that the preservation of a commons is vital if real innovation is to be nurtured here. This means, for example, that when analogue TV is switched off, some of the liberated spectrum should be retained as an unlicensed commons so that people can experiment and innovate with it.

Like all great ideas, it's simple. The only question is whether it's simple enough for the DTI to get it.

Source: Naughton (2002)

Modular Innovation

Modular innovation uses the architecture and configuration associated with the existing system of an established product., but employs new components with different design concepts. In terms of Henderson and Clark's framework, modular innovation is in the top right quadrant.

MINI-CASE: CLOCKWORK RADIO

An example of this type of innovation would be the clockwork radio, developed by Trevor Baylis. Radios have been around for a very long time. They operate on the basis of electrical energy, normally provided via either an external power supply or

batteries. The clockwork radio is an innovation that employs a different form of power supply, one that utilises a spring-based clockwork mechanism. The other components of the radio, such as the speakers, tuner, amplifier, receiver etc remain unchanged. As a radio, the clockwork radio operates in the same way as other radios. It employs the same kind of architecture in which the various components that make up the system are configured and linked together in the normal way. However being clockwork it does not require an external power sources and this is a very valuable feature in those parts of the world which don't benefit from regular uninterrupted power supplies.

Source: Baylis (1997)

As with incremental innovation, modular innovation doesn't involve a whole new design. However modular innovation does involve new or at least significantly different components. In the case of the clockwork radio it is the power source that is new. The radio operates in much the same way as any other radio.

The use of new or different components is the key feature of modular innovation, especially if the new components embrace a new technology. New technology can transform the way in which one or more components within the overall system operate, but the system and its configuration/architecture remains unchanged.

Clearly the impact of modular innovation is usually less dramatic than is the case with radical innovation. The clockwork radio illustrates this well. People still listen to the radio in the way they always have. But the fact that it doesn't need an external power source means that new groups often living in relatively poor countries without access

to a stable and reliable supply of electricity living can get the benefit of radio. Clockwork radio has also opened up new markets in affluent countries, for example hikers who want a radio to keep in touch with the outside world. Clockwork radio has also provided an important 'demonstration' effect as it has led to other products, such as torches, being fitted with this ingenious and environmentally friendly source of power.

Architectural Innovation

With architectural innovation, the components and associated design concepts remain unchanged but the configuration of the system changes as new linkages are instituted. As Henderson and Clark (1990, p12) point out,

> *'the essence of an architectural innovation is the reconfiguration of an established system to link together existing components in a new way.'*

This is not to say that there won't be some changes to components. Manufacturers may well take the opportunity to refine and improve some components, but essentially the changes will be minor leaving the components to function as they have in the past but within a new re-designed and re-configured system.

MINI-CASE: SONY WALKMAN

The Sony Walkman provides a good example of architectural innovation. The Walkman when it first came out was a highly innovative new product, but it involved

little or no new technology. All the main components that went into the Walkman were tried and tested having been used on a variety if other products. Portable audio tape recorders that could both play and record music had been on the market for many years. Designers at Sony, started with an existing small audio cassette tape recorder, the Pressman (Henry and Walker, 1991), a small lightweight tape recorder designed for press reporters. They proceeded to remove the recording circuitry and the speakers, and added a small stereo amplifier. A set of lightweight headphones completed the package. Because there were no speakers the new machine needed much less power. The absence of speakers meant it could be made much smaller while the fact that it needed much less power meant it could use only small batteries making it very much lighter. Thus a very different kind of system with a very different kind of architecture began to emerge. And so the Walkman was borne. It was new type of audio product. It was a personal stereo, that enable its young, mobile users to listen to music whenever and wherever they wanted, and without being harassed by older generations concerned about noise.

Source: Sanderson and Uzmeri (1995)

The Walkman was a huge commercial success, selling 1.5 million units in just two years (Sanderson and Uzumeri, 1995) . However the significance of the Walkman is not just that it sold well. It illustrates the power that is sometimes associated with architectural innovations. As well as securing Sony's future as a consumer electronics manufacturer, it had much wider impact on society. It was soon copied by other manufacturers, but more significantly it changed the behaviour of consumers. Young people found they could combine a healthy lifestyle while continuing to listen to

music so that the Walkman may be said to have helped promote a whole range of activities like the jogging, walking and the use of the gym.

THE VALUE OF AN INNOVATION TYPOLOGY

None of the types of innovation outlined using this framework is entirely watertight. Inevitably there is overlap and there will be many occasions when it is a matter of judgement as to which category an innovation should be placed in. However, this is not really an issue. What matters is the general value that comes from attempting a categorisation of innovations. Categorization, and in particular this form of categorization, helps to show that innovations are not homogeneous. Innovations vary. Consequently any analysis of innovation needs a degree of sophistication that can isolate exactly where the nature of the innovation lies. In the process this should enable the more discerning analysts to cast a more critical eye upon some of the wilder claims surrounding objects that are described using that much over-used adjective: *'innovative'*.

Categorizing innovations in this way can also help to show that the influence of technology and technological change can vary considerably. Technology works in a variety of ways. However its impact will differ enormously when applied to whole systems or when, for comparison, it is applied to individual components. Hence this form of categorization has a predictive power, such that those who use it can much more effectively evaluate the potential impact of a particular innovation.

Distinguishing four different types of innovation can also help to explain why the responses of firms to the introduction of new technologies will often vary. The analysis means that perhaps we should not be surprised that some firms don't respond positively to some new technologies. If the technology affects components we can expect a rapid take-up of a new technology, because it is likely to reinforce the competitive position of incumbent manufacturers. On the other hand if the technology leads to system changes and the introduction of new architectures then the incumbents are less likely to be happy about the changes as their position will be eroded. In Schumpeter's words we are likely to see 'creative destruction' at work.

This typology can also help in understanding the evolutionary process associated with technological change. When a new technology appears it frequently leads to a proliferation of competing system designs each with a different architecture. One could see exactly this happening when the first cars were developed – there was a multiplicity of competing architectures, and again when the first video recorders appeared. But through a process of 'shakeout' eventually a common system architecture or 'dominant design' evolved and was adopted by all manufacturers. This kind of evolutionary process is in fact very common and it has big implications for would be innovators and entrepreneurs who need to recognise that if they enter the industry during the early years there is likely to be a period of shakeout eventually. Even more important they need to recognise that the dominant design that does eventually emerge is not always technically superior to its rivals. The Qwerty keyboard is evidence that sometimes technically inferior designs emerge as the dominant design.

CASE STUDY: THE GUTS OF THE NEW MACHINE

(This is an abridged version of an a article from The New York Times, 30th November 2003)

Two years ago this month, Apple Computer released a small, sleek-looking device it called the iPod. A digital music player, it weighed just 6.5 ounces and held about 1,000 songs. There were small MP3 players around at the time, and there were players that could hold a lot of music. But if the crucial equation is "largest number of songs" divided by "smallest physical space," the iPod seemed untouchable. And yet the initial reaction was mixed: the thing cost $400, so much more than existing digital players that it prompted one online skeptic to suggest that the name might be an acronym for "Idiots Price Our Devices."

Since then, however, about 1.4 million iPods have been sold. For the months of July and August, the iPod claimed the No. 1 spot in the MP3 player market both in terms of unit share (31 percent) and revenue share (56 percent), by Apple's reckoning. It is now Apple's highest-volume product. Whether the iPod achieves truly mass scale -- like, say, the cassette-tape Walkman, which sold an astonishing 186 million units in its first 20 years of existence -- it certainly qualifies as a hit and as a genuine breakthrough.

So you can say that the iPod is innovative, but it's harder to nail down whether the key is what's inside it, the external appearance or even the way these work together. One approach is to peel your way through the thing, layer by layer.

The Aura

Before you even get to the surface of the iPod, you encounter what could be called its aura. The commercial version of an aura is a brand, and while Apple may be a niche player in the computer market, the fanatical brand loyalty of its customers is legendary. Leander Kahney has even written a book about it , "The Cult of Mac". As he points out, that base has supported the company with a faith in its will to innovate -- even during stretches when it hasn't. Apple is also a giant in the world of industrial design. The candy-colored look of the iMac has been so widely copied that it's now a visual cliché.

But the iPod is making an even bigger impression. Bruce Claxton, who is the current president of the Industrial Designers Society of America and a senior designer at Motorola, calls the device emblematic of a shift toward products that are "an antidote to the hyper lifestyle," which might be symbolized by hand-held devices that bristle with buttons and controls that seem to promise a million functions if you only had time to figure them all out. "People are seeking out products that are not just simple to use but a joy to use." Moby, the recording artist, has been a high-profile iPod booster since the product's debut. "The kind of insidious revolutionary quality of the iPod," he says, "is that it's so elegant and logical, it becomes part of your life so quickly that you can't remember what it was like beforehand."

The idea of innovation, particularly technological innovation, has a kind of aura around it, too. Imagine the lone genius, sheltered from the storm of short-term commercial demands in a research lab somewhere, whose tinkering produces a sudden and momentous breakthrough. Or maybe we think innovation begins with an epiphany, a sudden vision of the future. Either way, we think of that one thing, the

lightning bolt that jolted all the other pieces into place. The Walkman came about because a Sony executive wanted a high-quality but small stereo tape player to listen to on long flights. A small recorder was modified, with the recording pieces removed and stereo circuitry added. That was February 1979, and within six months the product was on the market.

The iPod's history is comparatively free of lightning-bolt moments. Apple was not ahead of the curve in recognizing the power of music in digital form. Various portable digital music players were already on the market before the iPod was even an idea. The company had, back in the 1990's, invented a technology called FireWire, which is basically a tool for moving data between digital devices -- in large quantities, very quickly. Apple licensed this technology to various Japanese consumer electronics companies (which used it in digital camcorders and players) and eventually started adding FireWire ports to iMacs and creating video editing software. This led to programs called iMovie, then iPhoto and then a conceptual view of the home computer as a "digital hub" that would complement a range of devices. Finally, in January 2001, iTunes was added to the mix.

And although the next step sounds prosaic -- we make software that lets you organize the music on your computer, so maybe we should make one of those things that lets you take it with you -- it was also something new. There were companies that made jukebox software, and companies that made portable players, but nobody made both. What this meant is not that the iPod could do more, but that it would do less. This is what led to what Jonathan Ive, Apple's vice president of industrial design, calls the iPod's "overt simplicity." And this, perversely, is the most exciting thing about it.

The Surface

The surface of the iPod, white on front and stainless steel behind, is perfectly seamless. It's close to impenetrable. You hook it up to a computer with iTunes, and whatever music you have collected there flows (incredibly fast, thanks to that FireWire cable) into the iPod -- again, seamless. Once it's in there, the surface of the iPod is not likely to cause problems for the user, because there's almost nothing on it. Just that wheel, one button in the center, and four beneath the device's LCD screen.

"Steve (Jobs) made some very interesting observations very early on about how this was about navigating content," Ive says. "It was about being very focused and not trying to do too much with the device -- which would have been its complication and, therefore, its demise. The enabling features aren't obvious and evident, because the key was getting rid of stuff."

Later he said: "What's interesting is that out of that simplicity, and almost that unashamed sense of simplicity, and expressing it, came a very different product. But difference wasn't the goal. It's actually very easy to create a different thing. What was exciting is starting to realize that its difference was really a consequence of this quest to make it a very simple thing."

Only Apple could have developed the iPod. Like the device itself, Apple appears seamless: it has the hardware engineers, the software engineers, the industrial designers, all under one roof and working together. "As technology becomes more complex, Apple's core strength of knowing how to make very sophisticated technology comprehensible to mere mortals is in even greater demand." This is why, (Jobs) said, the barrage of devices made by everyone from Philips to Samsung to Dell that are imitating and will imitate the iPod do not make him nervous. "The Dells of the world

don't spend money" on design innovation, he said. "They don't think about these things."

As he described it, the iPod did not begin with a specific technological breakthrough, but with a sense, in early 2001, that Apple could give this market something better than any rival could. So the starting point wasn't a chip or a design; the starting point was the question, What's the user experience? "Correct," Jobs said. "And the pieces come together. If you start to work on something, and the time is right, pieces come in from the periphery. It just comes together."

The Guts

What, then, are the pieces? What are the technical innards of the seamless iPod? What's underneath the surface? A lot of people were interested in knowing what was inside the iPod when it made its debut. One of them was David Carey, who for the past three years has run a business in Austin, Tex., called Portelligent, which tears apart electronic devices and does what might be called guts checks. He tore up his first iPod in early 2002.

Inside was a neat stack of core components. First, the power source: a slim, squarish rechargeable battery made by Sony. Atop that was the hard disk -- the thing that holds all the music files. At the time, small hard disks were mostly used in laptops, or as removable data-storage cards for laptops. So-called 2.5-inch hard disks, which are protected by a casing that actually measures about 2 3/4 inches by 4 inches, were fairly commonplace, but Toshiba had come up with an even smaller one. With a protective cover measuring just over 2 inches by 3 inches, 0.2 inches thick and

weighing less than two ounces, its 1.8-inch disk could hold five gigabytes of data -- or, in practical terms, about a thousand songs. This is what Apple used.

On top of this hard disk was the circuit board. This included components to turn a digitally encoded music file into a conventional audio file, the chip that enables the device to use FireWire both as a pipe for digital data and battery charging and the central processing unit that acts as the sort of taskmaster for the various components. Also here was the ball-bearing construction underlying the scroll wheel.

Exactly how all the pieces came together -- there were parts from at least a half-dozen companies in the original iPod -- is not something Apple talks about. But one clue can be found in the device itself. Under the Settings menu is a selection called Legal, and there you find not just Apple's copyright but also a note that "portions" of the device are copyrighted by something called PortalPlayer Inc. That taskmaster central processing unit is a PortalPlayer chip.

Most early MP3 players did not use hard disks because they were physically too large. Rather, they used another type of storage technology (referred to as a "flash" chip) that took up little space but held less data -- that is, fewer songs. PortalPlayer's setup includes both a hard disk and a smaller memory chip, which is actually the thing that's active when you're listening to music; songs are cleverly parceled into this from the hard disk in small groups, a scheme that keeps the energy-hog hard disk from wearing down the battery.

Apple won't comment on any of this, and the nondisclosure agreements it has in place with its suppliers and collaborators are described as unusually restrictive. Presumably this is because the company prefers the image of a product that sprang

forth whole from the corporate godhead -- which was certainly the impression the iPod created when it seemed to appear out of nowhere two years ago. But the point here is not to undercut Apple's role: the iPod came together in somewhere between six and nine months, from concept to market, and its coherence as a product given the time frame and the number of variables is astonishing. Jobs and company are still correct when they point to that coherence as key to the iPod's appeal; and the reality of technical innovation today is that assembling the right specialists is critical to speed, and speed is critical to success.

Still, in the world of technology products, guts have traditionally mattered quite a bit; the PC boom viewed from one angle was nothing but an endless series of announcements about bits and megahertz and RAM. That 1.8-inch hard disk, and the amount of data storage it offered in such a small space, isn't the only key to the iPod, but it's a big deal. Apple apparently cornered the market for the Toshiba disks for a while. But now there is, inevitably, an alternative. Hitachi now makes a disk that size, and it has at least one major buyer: Dell.

The System

My visit to Cupertino happened to coincide with the publication of a pessimistic installment of The Wall Street Journal's Heard on the Street column pointing out that Apple's famous online music store generates little profit. About a week later Jobs played host to one of the "launch" events for which the company is notorious, announcing the availability of iTunes and access to the company's music store for Windows users. The announcement included a deal with AOL and a huge promotion with Pepsi. The message was obvious: Apple is aiming squarely at the mainstream.

This sounded like a sea change. But while you can run iTunes on Windows and hook it up to an iPod, that iPod does not play songs in the formats used by any other seller of digital music, like Napster or Rhapsody. Nor will music bought through Apple's store play on any rival device. This means Apple is, again, competing against a huge number of players across multiple business segments, who by and large will support one another's products and services. In light of this, says one of those competitors, Rob Glaser, founder and C.E.O. of RealNetworks, "It's absolutely clear now why five years from now, Apple will have 3 to 5 percent of the player market."

Jobs, of course, has heard the predictions and has no patience for any of it. Various contenders have come at the iPod for two years, and none have measured up. Nothing has come close to Apple's interface. Even the look-alike products are frauds. "They're all putting their dumb controls in the shape of a circle, to fool the consumer into thinking it's a wheel like ours," he says. "We've sort of set the vernacular. They're trying to copy the vernacular without understanding it." (The one company that did plan a wheel-driven product, Samsung, changed course after Apple reportedly threatened to sue.) "We don't underestimate people," Jobs said later in the interview. "We really did believe that people would want something this good, that they'd see the value in it.

The Core

What I had been hoping to do was catch a glimpse of what's there when you pull back all those layers -- when you penetrate the aura, strip off the surface, clear away the guts. What's under there is innovation, but where does it come from? I had given up on getting an answer to this question when I made a jokey observation that before long somebody would probably start making white headphones so that people

carrying knockoffs and tape players could fool the world into thinking they had trendy iPods.

Jobs shook his head. "But then you meet the girl, and she says, 'Let me see what's on your iPod.' You pull out a tape player, and she walks away."

Source: Walker, R. (2003) The Guts of the New Machine, New York Times, 30th November, 2003, p68.

Questions

1. *What is novel about the iPod?*
2. *What type of innovation would you class the Sony Walkman as and why?*
3. *What type of innovation would you class the iPod as and why?*
4. *What does the author man by 'lightening –bolt' moments?*
5. *If 'the iPod did not begin with a specific technological breakthrough ' as Steve Jobs maintains, how can it still be classed as an innovation?*
6. *What is licencing and why did Apple choose to licence its Firewire technology?*
7. *Why, according to the author, does innovation especially technological innovation, have an 'aura' around it? Give an example of another product with an aura.*
8. *What do you think Steve Jobs means when he says that the iPod is about 'navigating content'?*
9. *Why does Steve Jobs believe that imitators of the iPod like Dell, do not pose a threat?*

10. *By the end of 2004, total sales of iPods had reached 10 million. What does this imply about the prediction of Rob Glaser of RealNetworks for the iPod's market share?*

QUESTIONS FOR DISCUSSION

1. What is the value of being able to categorize innovations?
2. Why may large established firms be wary of radical (disruptive) innovations?
3. Why do product innovations tend to attract more public attention than service or process innovations?
4. Why do process innovations some times have wide-ranging consequences for society?
5. Identify two process innovations which have had a big impact on society.
6. Differentiate between component knowledge and system knowledge.
7. Choose an example of an everyday household object (e.g. an electric kettle) and identify some of the incremental innovations that have taken place.
8. Why are only a small proportion of innovations typically radical?
9. Why is the Sony Walkman an example of architectural innovation?
10. What type of innovation is Apple's iPod?

ASSIGNMENTS

1. Using any household object of your choice (e.g. vacuum cleaner, hairdryer etc) identify and analyse the following:

a. System function
b. Components
c. System linkages
d. Incremental innovation

Outline what you consider to be the rationale behind ONE recent incremental innovation.

2. Identify a product that has been the subject to modular innovation. Analyse where the innovation has occurred and the impact this has had on the product. Explain why you think this is a case of modular innovation, noting how the system architecture has remained unchanged.

3. What is a system? Take an example of a system and analyse it using a diagram to show the components and the linkages between them. Indicate where there have been examples of a.) incremental innovation b.) architectural innovation.

4. What is meant by radical innovation? Take an example of radical innovation and analyse the impact it has had on society. Take care to differentiate between the different groups within society that have been affected.

5. What is meant by the term ‘creative destruction’. Explain, using appropriate examples, the link between creative destruction and radical innovation.

RESOURCES

The paper by Henderson and Clark(1990) that appeared in Administrative Science Quarterly , provides an excellent starting point for classifying and categorizing innovations. It draws on earlier work to provide a fourfold typology.

Two of the categories, radical and incremental innovation have substantial literatures of their own. Incremental innovation is covered by works such as Nelson and Winter (1982), Ettlie, Bridge and O'Keefe (1984) and Tushman and Anderson (1986). Radical innovation on the other hand overlaps with other aspects of innovation such as technological discontinuities and crops up in sources as diverse as Schumpeter (1942), Rothwell (1986) and Christensen (1997).

When it comes to the product, process and service categorization of innovation one finds that product innovations are comparatively well served , but service and process innovations have attracted much less attention. The main reason for this is that product innovation falls within the remit of histories of invention while service and process innovations do not. Among the many excellent histories of invention that give valuable insights into the events surrounding the development process associated with product innovations are studies by Van Dulken (2002) and Nayak and Ketteringham (1993) which provide short outlines of many well-known product innovations. In addition there are a number of other texts with a strong American focus including Basalla (1988), Hughes (1989) and Petroski (1992). Basalla (1988) is particularly interesting because its focus is on the evolution of technology and the links between different innovations.

Service innovations are much more poorly served, largely because technology is often less in evidence and because there is no tangible object. While it focuses mainly on product innovations, the study by Nayak and Ketteringham (1993) is one of the few to cover some well-known examples of service innovations including Federal Express and Club Mediterranée. Similar studies that include examples of service innovations are Davis (1987) and Henry and Walker (1991).

Process innovations are often the hardest to research. They are often well known but acquiring detailed data about them can be difficult. Industry studies, that is to say studies of how an industry has developed over time can provide valuable, detailed insights. Examples include Womack et al.'s (1990) study of the motor industry, Chapman's (2002) study of the knitting and hosiery branches of the industry, and Dogannis' (2001) study of the airline industry. The first of these is the product of a huge study of the motor industry undertaken in the late 1980s. It provides a lot of detail about mass production – one of the most significant process innovations, as well as later developments such as lean manufacturing. A more specialised study that focuses on the regional rather than the international level is Chapman's (2002) study of knitting and textiles. It builds on earlier work stretching back to the 1960s and shows how process innovations transformed the textile industry. Dogannis has written a number of studies of the airline industry. Dogannis (2001) covers a number of process innovations associated with aircraft. Another important study of the same industry is Hanlon (1999) who provides insights into a number of process innovations including computer reservation systems and hub-and-spoke operations.

REFERENCES

Basalla, G. (1988) *The Evolution of Technology*, Cambridge University Press, Cambridge.

Baylis, T. (1999) *Clock This: My Life as an Inventor*, Headline Publishing

Cassidy, J. (2002) *Dot.con: the greatest story ever sold*, Penguin Books, Harmondsworth.

Chapman, S.D. (2002) *Hosiery and Knitwear: Four Centuries of Small-Scale Industry in Britain c1589-2000,* Pasold Research Fund/Oxford University Press, Oxford.

Christensen, C.M. (1993) *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*, Harvard Business School Press, Boston, Mass.

Davis, W. (1987) *The Innovators*, Ebury Press, London.

Dogannis, R. (2001) *The airline business in the 21st century*, Routledge, London.

Dyson, J. (1997) *Against the odds: An Autobiography*, Orion Business.

Ettlie, J.E., Bridges, W.P. and O'Keefe, R.D. (1984) Organizational strategy and structural differences for radical vs. incremental innovation, *Management Science*, 30, pp682-695.

Freeman, C. and Louçã, F. (2001) *As Time Goes By: From Industrial revolutions to Information Revolution,* Oxford University press, Oxford.

Hanlon, P. (1999) *Global Airlines: Competition in a transnational industry*, Butterworth-Heinemann, Oxford.

Henderson, R.M. and Clark, K.B. (1990) Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms, *Administrative Science Quarterly*, 35 pp9-30.

Henry, J. and Walker, D. (1991) *Managing Innovation*, Sage Publications.

Hughes, T.P. (1989) *American Genesis: A Century of Innovation and Technological Enthusiasm 1870-1970,* Viking, NY.

Howells, J. (2005) *The Management of Innovation and Technology*, Sage Publications, London.

Kamm, A. and Baird, M. (2002) *John Logie Baird*, National Museum of Scotland.

Naughton, J. (2002) Never ask permission to innovate, *The Observer*, 3rd November 2002, p17.

Nayak, P.R. and Ketteringham, J.M. (1993) *Breakthroughs!* Mercury Business Books, Didcot.

Nelson, R. and Winter, S. (1982) *An Evolutionary Theory of Economic Change,* Cambridge University Press, Cambridge.

Petroski, H. (1992) *The Evolution of Useful Things,* Alfred A. Knopf, NY.

Procter, J. (1994) Everyone versus South West, *Airways*, November-December 1994, pp22-29.

Quinn, J.B. (1991) *The Strategy Process: Concepts, Contexts, Cases*, Prentice Hall, Englewood Cliffs, NJ.

Rothwell, R. (1986) The role of small firms in the emergence of new technologies, in Freeman, C. (ed.) *Design, Innovation and Long Cycles in Economic Development*, Frances Pinter, London, pp231-248.

Rothwell, R. and Gardner, D. (1989) The strategic management of re-innovation, *R & D Management*, 19 (2) pp147-160.

Sanderson, S. and Uzumeri, M. (1995) Managing product families: The case of the Sony Walkman, *Research Policy*, 24, pp761-782.

Thompson, D. (1996) *The Oxford Compact Dictionary*, Oxford University Press, Oxford.

Tushman, M.L. and Anderson, P. (1986) Technological discontinuities and organisational environments, *Administrative Science Quarterly*, 31, pp439-465.

Van Dulken, S. (2002) *Inventing the 20th Century: 100 Inventions that Shaped the World,* British Library, London.

Walker, R. (2003) The Guts of the New Machine, *The New York Times*, 30th November 2003, p68

Womack, J.P. , Jones, D.T. and Roos, J. (1990) *The Machine that Changed the World*, Rawson Associates, NY.