Part 1

The nature of innovation

Chapter 1

What is innovation?

Learning Objectives

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

- Appreciate the varied nature of innovations
- Identify, differentiate and analyse the five forms of innovation identified by Joseph Schumpeter
- Analyse the characteristics of these different forms of innovation
- Analyse the degree of novelty associated with different types of innovation such as radical and incremental innovation
- Appreciate the impact that innovations can have by virtue of their form and/or the degree of novelty.

Innovation – what is it?

We hear a lot about innovation. Innovations, especially technology-based ones like the iPhone – the first mobile phone to offer a multi-touch interface – attract a great deal of media attention and public interest. Indeed, Atkinson and Ezell (2009: 129) suggest that most people believe that innovations only comprise 'shiny new products' produced by companies like Apple. Media attention often occurs when the innovation first appears and the number of users is comparatively modest. Driven by a heady cocktail of novelty, scarcity and uncertainty, a new product or service becomes newsworthy and much is said and written about it. Perez (2002: 3) describes this as 'technological euphoria'. Typically, it involves speculation about the potentially rapid take-up of the innovation and the dramatic impact it is likely to have on our lives. This is not unconnected to what Naughton (2008a) refers to as the 'first law of technology' whereby we, that is, the media and the public, tend to overstate and exaggerate the short-term impact of new technology (although he goes on to note that we often understate the long-term impact).

Nor is interest in innovation confined to the general public. Politicians and policymakers often take a keen interest too. Harold Wilson, Britain's Prime Minister in the 1960s and early 1970s, captured the excitement and inherent possibilities of technological innovation when he famously spoke of the 'white heat' of technological innovation as a powerful modernizing force in society. Similarly, in the economic downturn that followed the financial crisis of the late 2000s, politicians in both the UK and the USA extolled the virtues of innovation as some kind of 'elixir' (Chakrabortty, 2013) in which designing and developing new products and services would generate new sources of wealth and drag Western economies out of the slump. Though this interest is typically fuelled by exactly the same forces, such as media interest and media attention, there is a more logical explanation for politicians' interest, since as economists like William Baumol (Dodgson and Gann, 2010: 18) and others have shown, much of the economic growth that has brought increased prosperity and rising living standards since the Industrial Revolution is attributable to innovation, particularly technological innovation.

Not to be outdone, the financial markets, too, frequently show much interest in innovation, so much so that in the right circumstances, the value of shares of innovating companies can power to dizzying heights, making millionaires and even billionaires of those who backed the innovation (and sometimes those who actually developed it too!). For instance, when Twitter, the San Francisco-based firm that developed the now well-known microblogging service, was floated on the New York Stock Exchange (NYSE) in November 2013, its shares, which were initially offered at $26 each, rose on the first day to $44.90 valuing the company, which had never made a profit, at a cool $31 billion. However, the value of the company rose comparatively slowly after the IPO, so that when Elon Musk bought Twitter in 2022, it cost him a modest $44 billion. Nonetheless, in financial terms, it is the case that innovations often represent or appear to represent a very big deal.

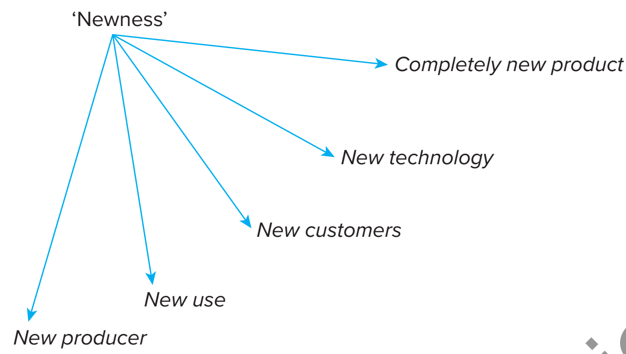
So if innovation is something that attracts a lot of attention and that lots of people are interested in and regard as important – what exactly is it? Newness and novelty are key aspects of innovation. Indeed, the term is derived from the Latin word *novus,* meaning new or novel.

As Figure 1.1 shows, the 'newness' associated with innovation can vary considerably in terms of just what is new. It can range from a new product or artefact, to a new technology or new uses for an existing product, or new customers, or simply a product that is new for to a particular firm. This is captured in Rogers' (2003) definition of innovation which refers to differences in 'newness':

> "*An innovation is an idea, practice or object that is perceived as new by an individual or other unit of adoption.*"
>
> Rogers (2003: 12)

There is, however, more to innovation than simply newness and novelty. Atkinson and Ezell (2009: 129) note that notions of newness and novelty are limiting because innovation is about much more than something being new. An invention is something new, but it is not the same thing as innovation. An innovation, as well as being novel and new, has to be 'a viable business concept'. In other words, innovation is about the development of something new and its implementation into a viable product that is marketed and that consumers can purchase. Only when something new appears on the market so that it can be

Figure 1.1 Different forms of 'newness'



bought and sold, can the idea be said to be an innovation. This is captured in the OECD definition of innovation, which defines the concept as:

> *the implementation of a new or significantly improved product (good or service), or process, new marketing method, or a new organisational method in business practices, workplace organisation or external relations.*
>
> OECD (2005)

Complicated though this definition may appear to be, in this context, the word 'implementation' is critically important because unlike invention, which is primarily a creative process involving the creation of something new, innovation is about more than this as it involves turning the idea into something viable and getting it onto the market so that consumers can acquire it. In short, to be an innovation, an invention has to be commercialized and marketed.

There is another very important facet of the OECD's definition. Up to this point, the discussion has operated on the assumption that an innovation is a product (or a service). Given that most people tend to think of innovations as being artefacts, i.e. products, this is not surprising. But the OECD definition goes much further than this. It identifies innovations as not merely covering new products or services but taking a variety of different forms such as new processes, new marketing methods or new organizational methods. Hence the OECD definition dramatically extends the *form* that innovations may take, well beyond the notion that they comprise products and services. This broad interpretation of what constitutes an innovation aligns with the work of the Austrian economist Joseph Schumpeter (1883–1950).

The forms of innovation

Schumpeter was one of the most influential economists of the twentieth century. Significantly he was among the first to explore and theorize about the concept of innovation. Previously economists had tended to assume that economic systems naturally tended towards stability and equilibrium. Schumpeter in contrast was interested in the forces that could bring about instability, in particular the forces that bring about disturbances leading to change and thence economic growth. He even coined the term 'creative destruction' to describe the instability. This interest led him to focus on what he termed 'new combinations' of resources (i.e. land, labour and capital), brought together to yield new products and services. These new combinations are what we would call innovations. However, Schumpeter, like the OECD many years later, did not limit his notion of innovations to new products. Rather his new combinations comprised no less than five different forms of innovation:

1. new goods, i.e. products and services
2. new methods of production
3. opening of new markets
4. the development of new sources of supply of raw materials
5. new forms of organization.

Though massive technological advances have taken place in what is almost a century since Schumpeter (1934) first distinguished these forms of innovations, they have proved remarkably robust and still provide a very effective way of classifying innovations.

By goods, Schumpeter had in mind new products, i.e. physical artefacts, since at the time he was writing, most goods took this form. Even today, most people tend to associate innovations with new products. This is not entirely surprising since new products are typically a very visible manifestation of innovation. Modern examples of innovations in the form of new products would include things like the Apple iPhone, Tesla's electric car or LED lights. Many of these modern product innovations have had a big impact on our lives. Consequently, it is tempting to think that we are living in a period of unprecedented technological innovation. But that might well be a mistake. There have been plenty of product innovations in past periods that have, in their time, been just as transformational in terms of their impact. Innovations like the steam engine, the telegraph or electric light probably had as great an impact in terms of transforming the lives of the great mass of the population. The telegraph, for instance, permitted rapid (almost instant) communication over long distances for the first time. The steam engine, when applied to railways in the form of the steam locomotive, permitted travel at speeds many times faster than anyone had ever travelled before.

Product and service innovations

A feature of innovations in the form of new goods or products is that, like the historical examples identified in the previous section, they are typically technology-based. Hence, the 'newness' of a product innovation often comes about through advances in science or the application of developments in technology. Schumpeter argued that these advances require companies to possess extensive research and development (R&D) facilities, and certainly this was the case for most of the latter part of the twentieth century. As Table 1.1 indicates, decade by decade, for much of the twentieth century, most of the leading product innovations were launched by large corporations with extensive R&D laboratories. Particularly notable was the research laboratory of the US-based telecoms giant American Telephone and Telegraph Company (AT&T). Not only was its Bell Labs R&D facility large, employing some 25,000 scientific and technical personnel at its peak, it was responsible for a string of notable product innovations. However, as Chapter 3 indicates, this is not necessarily the case today. The technological input

Table 1.1 Twentieth-century product innovations

Decade	Product innovation	Innovator	Country
1930s	Nylon	DuPont	USA
1940s	Instant camera	Polaroid	USA
1950s	Photovoltaic cell (solar power)	Bell Labs (AT&T)	UK
1960s	Ibuprofen: painkiller	Boots Pharmaceutical	USA
1970s	Microprocessor chip	Intel	USA
1980s	Compact disc (CD)	Sony	Japan
1990s	Viagra: erectile dysfunction drug	Pfizer	USA

to product innovations is now often so great that it is beyond the capability of a single organization. As a result, the technological input now tends to be derived from external as well as internal sources. These sources include technology licensing, joint ventures and similar forms of inter-firm co-operation.

The term 'goods' extends to more than products (i.e. physical artefacts). According to Toivenen and Tuominen (2009: 887), services were 'long regarded as secondary from the viewpoint of innovation'. Yet today, in most the Global North, something like 75 per cent of gross national product (GNP) is derived from services (Lehtinen and Järvinen, 2015). Not unsurprisingly, service innovations make up a significant proportion of today's innovations (Lehtinen and Järvinen, 2015). In the last 20 years, we have seen successive waves of new service innovations, in many cases resulting in rapid growth for the organizations behind them and turning the innovators themselves into billionaires.

According to Den Hertog (2000), service innovations can be categorized into three broad groups: new service concepts, new client interfaces and new forms of service delivery. A new service concept involves offering a completely new kind of service. Den Hertog cites the case of call centres as an example of a service innovation in the form of new service concept. Prior to their introduction, customer enquiries at banks, utilities and similar organizations were typically handled through visiting a high street branch of the organization concerned. Here staff could provide a direct person-to-person service. One of the pioneers of the call centre concept was the credit card company Barclaycard, which established its first call centre at its operational base in Northampton back in the 1970s. This provided a means of handling customer enquiries on a centralized basis, rather than relying on a multiplicity of high street branches. Recent examples of service innovations that take the form of new service concepts would include social media such as Facebook and Instagram. They provide a form of social networking unlike anything that went before and they were made possible by the internet. Perhaps not unsurprisingly, the development of the internet lies behind much of the dramatic increase in service innovations that has taken place in recent years.

New client interfaces represent another form of service innovation. These typically take the form of a new interface between the client and the service provider. Often, this will involve a change from delivering the service by interacting with a member of staff to interacting with a machine. Many supermarkets, for example, now make extensive use of self-checkouts, or SCOs, where the shopper takes on the role of cashier and scans and pays for their shopping. The basic service in the form of shopping remains the same, but the client interface has changed from one involving staff to one involving a machine.

The third type of service innovation involves a new form of service delivery. Netflix provides a good example of this form of service innovation. At one time, video rentals were based in retail outlets. Films and TV programmes were available on videocassettes and these could be rented by visiting a rental store and making a selection. As DVDs began to replace videocassettes, Netflix introduced a service whereby films and TV programmes were mailed out to customers. The increasing availability of internet technology meant customers could select what they wanted to watch online, thus dispensing with costly retail premises. By 2007, advances in technology combined with the continued growth of the internet enabled Netflix to introduce a new form of service delivery – video-on-demand via video streaming. Latterly, even terrestrial TV services, such as the BBC and ITV in the UK, have adopted streaming services, allowing them to offer video-on-demand services such as iPlayer and ITVX.

The availability of the internet is behind many of the current crop of service innovations. It not only offers a platform that would-be innovators can utilize to facilitate distribution, the actual innovation requires the development of software rather than expensive investments in technology development through R&D. The internet has also helped to transform a range of existing services. Thus banking, travel and a range of other services have changed dramatically with the introduction of service innovations based on online services.

Innovations in methods of production

The second form of innovation identified by Schumpeter was new methods of production, commonly described as process innovations. In short, these are innovations associated with new ways of making things or delivering services. Often described as the least exciting form of innovation, they are frequently overlooked despite very often having a dramatic impact on our lives. These innovations typically result in the development of ways of producing things more rapidly, in greater quantities and much more efficiently, leading to significantly lower costs. More efficient production thus results in greater demand and higher incomes.

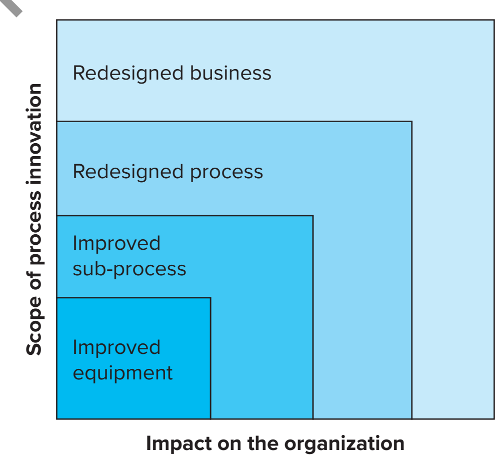
The impact of these efficiency gains resulting from improved manufacturing methods and processes can be both impressive and far-reaching. Leung and Voth (2011) cite the case of Henry Ford and his introduction of the moving assembly line in the second decade of the twentieth century. This reduced the time taken to assemble a car from 12.5 hours in the spring of 1913 to 1 hour and 33 minutes a year later. These efficiency gains led Ford to reduce the price of his Model T car, from $960 in 1909 to $360 in 1916. As a result of this massive reduction in price, sales increased dramatically and so too did the output of Model Ts. They became so commonplace that in his novel *Cannery Row*, John Steinbeck (1945) wrote: 'Most of the babies of the period were conceived in Model T Fords and not a few were born in them.'

Leung and Voth (2011) estimate that the value of Ford's innovation was worth around 1.8 per cent of GDP. This may look like a relatively small number, but US GDP even in the first half of the twentieth century was huge. Leung and Voth (2011) note that in the process, Ford made himself rich and created thousands of new jobs but most of the benefits of his innovation went to the people who bought his cars. Such is the power of process innovations.

Impressive though Ford's achievements may be, a much earlier process innovation in the fifteenth century had an even greater impact. Johannes Gutenberg's innovation of the printing press using movable metal type introduced in 1455 was to transform European society. It allowed the mass production of books for the first time. Previously, books had been painstakingly written out by hand. This was a very slow and laborious process. In contrast, Gutenberg's printing press allowed books to be produced more rapidly, in much greater quantities and at much lower cost. Significantly, knowledge became much more widely available across society. This process innovation led in time to transformative movements such as the Renaissance and the scientific revolution of the sixteenth and seventeenth centuries.

In reality, process innovations are even more diverse than service innovations. In Schumpeter's terms, new processes cover new ways of making and producing products. This implies changes to the production equipment, methods and systems of firms that manufacture products. However, it can be useful to portray process innovations as occurring on different levels. This allows for a much broader interpretation of what is meant by process innovation and provides scope for embracing some of Schumpeter's ideas (see Figure 1.2).

Figure 1.2 Levels of process innovation



At the lowest level, we have changes in the equipment that forms part of a production system. Good examples would be the introduction of numerically controlled (NC) machine tools and then computer numerically controlled (CNC) machine tools, which transformed manufacturing processes that involved cutting metal by reducing the level of skill required of machine tool operators and both sped up and increased the accuracy of machining operations. At this level, the new equipment introduced as a process innovation is frequently designed to make labour-intensive processes more efficient through the introduction of capital-intensive equipment (Swann, 2009).

At the next level, we have improvements in sub-processes within manufacturing systems. Examples here would include things like modular design and manufacturing cells. The latter involves grouping together items of manufacturing equipment, such as machine tools, to enable them to focus on the production of a particular class or type of product. It is basically a way of redesigning and reorganizing a part of a production system in order to make it more efficient.

At the third level, one has the introduction of entirely new production processes. These are likely to involve not merely the introduction of new equipment but a wholly redesigned process, probably involving a new and perhaps very different technology. A classic example of a redesigned process also involving the introduction of a new technology is the 'float glass' process developed by Alistair Pilkington, at the British glassmakers Pilkington Bros (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. The only way of getting a flat surface was to grind and then polish finished sheets of glass. This was a slow and laborious process. At a stroke, the float glass process dispensed with grinding and polishing equipment. In its place came an entirely new technology, with plate glass manufactured by drawing molten glass out of a furnace and across a bed of molten tin in order to yield a perfectly flat surface. It led to a dramatic fall in the cost of making plate glass. Architects and property developers could now afford to specify large sheets of plate glass when constructing new buildings. The result can be seen in building construction in the past 30 years, where everything from office blocks and hotels to airports and shopping malls and even universities now employ large expanses of glass.

An example of a service business being transformed through the introduction of a redesigned process that utilizes new technology would be SABRE, the computerized airline reservation system introduced by American Airlines (Campbell-Kelly, 2003), which provides an example of a service innovation brought about by improved equipment, namely the computer. When first introduced in the late 1960s, SABRE transformed the experience of air travel because, for the first time, it became possible for travel agents booking passengers onto flights to ascertain accurately whether an airline had vacant seats on a particular flight. Prior to SABRE, airlines could only estimate how many people had booked to fly. Passengers were required to 'confirm' their booking by telephone before the flight and airlines left a certain proportion of seats empty to cover bookings still being processed by the unwieldy paper-based systems then being used. Not only did the uncertainty mean a poor quality of service for passengers, it often led to low load factors on many flights, inevitably making flying more expensive. SABRE paved the way for the massive growth in air travel that has occurred in recent decades.

The fourth level of process innovation involves what might be described as managerial innovations. These have little to do with the introduction of new technology and more to do with how the business is managed and run. These innovations are more about methods than about technologies. Examples would include things like F.W. Taylor's 'scientific management' – sometimes referred to as work study or organization and methods (O&M) – which in its time was a way of organizing work that led to big increases in productivity as work activities were reorganized using Taylor's principles of scientific management. Other examples would include just-in-time production, total quality management (TQM) and lean production (Table 1.2 on the next page). These are all ways of managing production. However, they are not confined to the factory floor. They are ways of managing a business and require commitment at every level of the organization. They can be classified as ways in which one can redesign a business.

As noted earlier, process innovation is something of a 'Cinderella' topic, but this does not mean it should be underestimated. One of the key concepts that Joseph Schumpeter introduced was the notion of 'creative destruction' where innovation leads to the rise of new industries and the demise of old established ones. Such dramatic changes, which can sweep away whole industries relatively quickly, do not normally come about as a result of product or service innovations but through process innovations.

Table 1.2 Technological versus managerial forms of process innovation

Technological	Managerial
NC and CNC machine tools	Fordism (mass production)
Industrial robotics	Scientific management (Taylorism)
Float glass	Lean production
SABRE computerized flight reservation system	Just-in-time (JIT)
Electronic point of sale (EPOS)	Total quality management (TQM)

In the early years of the nineteenth century, there were frequent outbreaks of rioting and civil disorder as workers broke into local textile mills to destroy textile machinery. The Luddites, as they were known, were particularly prevalent in the Midlands region of the UK, especially in and around Nottingham (Chapman, 2002). Here, it was stocking knitters, who traditionally worked on knitting frames located in their homes, that took to rioting and breaking the new, more efficient machines located in factories. They feared 'creative destruction' as the new factory-based machines made knitting frames redundant and destroyed their livelihoods, a testimony to the power of process innovation.

Market/business model innovations

Schumpeter's third form of innovation was the opening of new markets. This, he suggested, might encompass a firm entering a market that did not previously exist or simply one in which it had not previously traded. An example of a 'new market' is the development of the teenage market of the 1950s. In this decade, the post-war baby boom made adolescents the fastest growing demographic. This combined with an expanding economy meant they had more money and more leisure time than their parents brought up in the Depression years of the 1930s. Thus, in the years immediately after the Second World War, young people, almost for the first time as a group, began to be labelled as 'teenagers' and attract the attention of advertisers. As Ogerby (2008: 16) observed, 'during the late 1950s and early 1960s commercial interests scrambled to cash in on the goldmine represented by young people's spending'. This, in turn, led to a stream of products and services, such as music, beauty products and clothes, specifically targeting this apparently new market.

An example of a product targeted at the new teenage market of the 1950s would be the introduction of the transistor radio. Previously, radios were big, heavy, immobile objects powered by mains electricity. Very often, they resembled a piece of furniture and were treated as such, forming a focal point for family entertainment in the home. Following the invention of the transistor in 1947, the first transistor radio, the Regency TR-1, was launched in 1954 as the world's first commercial transistor radio. Unlike existing radio sets it was pocket-sized and battery-powered and appealed to the new and developing teenage market. Another example of a new market innovation would be the work of the Japanese video game company Nintendo. Having previously dominated the video game market, by the early 2000s Nintendo had been displaced by Sony and Microsoft. Instead of competing with these two larger technology giants head-on to create more sophisticated games consoles, Nintendo opted to create a new market as part of a radical Blue Ocean strategy (Ziesak and Barsch, 2019). Rather than the market for young, technically sophisticated 'hard core' gamers, Nintendo aimed to create a new untapped market for 'casual gamers'. Nintendo's Wii games console, launched in 2006, was technically less advanced than those of its rivals. Instead, it was aimed at attracting adults of all ages, including many who had hitherto had no interest in video gaming. To do this, the Wii offered a range of new features including a wand and a balance board that enabled users to physically engage in a range of sports and exercise activities. The realistic human – computer interface offered by the Wii proved attractive to non-gamers as did the broad range of activities offered by the new games console. Nintendo has continued to tap this market for casual gamers with the launch of the Nintendo Switch in 2017, a hybrid games console (i.e. a tablet that can either be used as a portable device or docked to form a console) that proved especially popular during the Covid-19 pandemic.

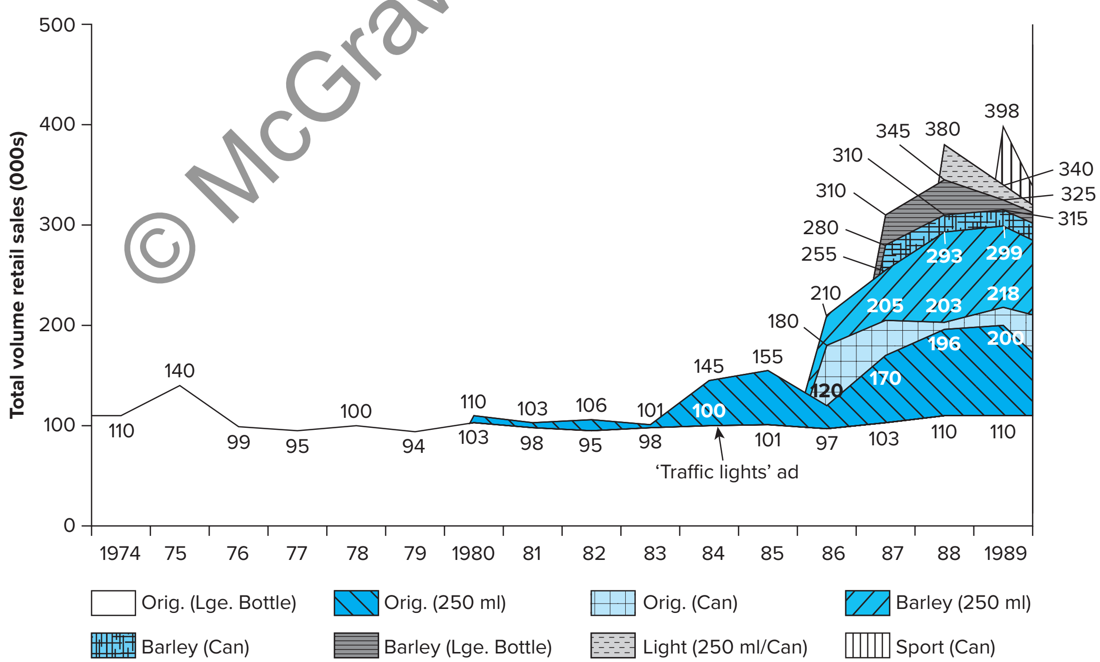
Entirely new markets like the one opened up by the Wii are comparatively rare. Much more common is the practice of companies that are established in one market deciding to enter another market or market segment in which they have not previously been represented. The case of the soft drink Lucozade offers a classic example of this practice. A long-established product made by a pharmaceutical company and sold by pharmacies for the healthcare market was targeted at a quite different market segment, namely the youth market. While the packaging and the promotion was changed, it remained essentially the same product.

Mini Case: Lucozade

Lucozade was developed by a Newcastle pharmacist called William Walker Hunter almost a century ago in 1927. It comprised a mixture of glucose and water and was sold in large glass bottles encased in a cellophane orange wrapper. It was aimed at the healthcare market, especially the convalescence of children recovering from illness supported by mothers. The idea was very much that as a palatable, easily digested glucose drink, Lucozade could be given to those who were unwell and suffering from loss of appetite, thereby aiding recuperation and speeding recovery. Hence it was advertised with the tag line, 'Lucozade aids recovery'. Reflecting the medicinal theme, Lucozade was only available from pharmacies. The business was purchased by the pharmaceutical company Beechams in 1938 and Lucozade continued to be marketed and promoted in the established manner for the next four decades.

Then with sales stagnant in the early 1980s, Beechams decided to forsake the healthcare market. Instead, it aimed to try to reposition Lucozade by targeting a very different market segment, namely energetic and lively teenagers and young adults, pursuing an active and often very mobile lifestyle, for whom the product represented an energy drink. Lucozade was now to be presented as a mass-market product. Reflecting this, it was no longer to be sold in pharmacies but in supermarkets and similar outlets and with an eye to the youth market, even in vending machines. Marketing, promotion and advertising changed dramatically. Out went the big glass bottle to be replaced by a smaller 250 ml plastic bottle.

Figure 1.3 Lucozade sales 1974–89



Source: Jackson (1994).

and cans. The use of a smaller bottle meant it was now much more portable and therefore suitable for use by active teenagers who might need a boost of energy to support their lifestyle. Not only that, they could drink Lucozade anywhere at any time and more quickly. Changes to the packaging undertaken as part of the rebranding included a new design for words on the packaging and the replacement of the old tag line with 'the original solution'. There was also a dramatic change to the advertising, especially those shown on TV. Out went mothers and small children, replaced by Olympic athlete Daley Thompson. An advertisement featuring Thompson on a running track with traffic lights famously marking the phases of a race, heralded a more sporting image for what was now being promoted as an energy drink (Jackson, 1994). Although additional flavours such as barley and orange (sport) were introduced, the basic product remained the same. The impact of the changes was soon evident as Lucozade sales increased dramatically in the second half of the 1980s (see Figure 1.3).

Source: Jackson (1994).

Latterly, researchers have extended Schumpeter's notion of market innovation to include innovations associated with the introduction of new business models. This reflects the greatly increased interest in and analysis of business models in recent years and the extent to which they are increasingly a feature of market development. Business models form a framework or recipe that enables firms to create and capture value from a product or service and, as a result, gain from it financially. Hence as a form of innovation, a business model represents a new or at least different way of making money from a product or service.

Historically, the normal way in which firms capture value is via outright sale of the product, where they set a price for a product and require customers to pay that price for ownership to be transferred. However, there are other ways of generating revenue. For example, when Gillette introduced the safety razor with replaceable blades more than a century ago, it introduced a new business model that relied on a different revenue-generating mechanism to the conventional price-based transaction where manufacturers made their money from the sale of the razor. Instead, Gillette charged a low price for the razor on which it made little or no profit but a high price for the replaceable blades. Because the blades could not be sharpened, they had to be replaced, thereby guaranteeing a steady income stream with a high level of profit. Henceforth, this became known as the 'razor and razor blades' business model. The growth of services where there is no actual transfer of ownership has led to the emergence of a much broader range of business models. Examples include advertising, subscription, freemium, leasing, licensing and usage fee business models (see Chapter 6).

New sources of supply

By new sources of supply, Schumpeter had in mind new supplies of raw materials coming on stream. At the time he was writing, major new sources of raw materials began to develop. In the first half of the twentieth century, Canada emerged as a world-leading producer of a wide range of minerals. Mines in the Canadian Shield produced not only precious metals but, increasingly, critical base metals such as copper, lead and zinc as well. It was a similar story though somewhat later in Australia, which emerged as a major source of key minerals such as iron ore, bauxite, nickel and copper. The availability of new supplies of raw materials not only helped to cover the exhaustion of supplies in many parts of Europe, it also gave a boost to the world economy.

Things like minerals and metals are not the only form that raw materials can take. Energy also constitutes an important raw material as far as the economy of the world is concerned. New sources of supplies of energy have emerged over the years, helping to balance the loss of energy supplies as sources become exhausted.

The USA has witnessed what has been described as a 'Shale Revolution' in the last two decades, dramatically opening up a major new source of energy from a situation where the country's domestic supply of oil and gas had steadily declined for many years. This so-called revolution has come about through technological developments in oil and gas extraction, in particular the development of hydraulic fracturing and horizontal drilling. These developments enabled the USA to significantly increase its production of oil and natural gas. This new production capacity has significantly reduced the country's dependence on oil imports from overseas. At the same time, it has provided a major boost to the country's economy, especially in the years immediately following the 2008 recession brought on by the financial crisis.

Shale is by no means the only new source of energy we have seen in recent years as various forms of renewable energy have become available. The two principal sources of renewable energy are wind and solar power, however other new sources of energy have emerged in recent years including hydrogen production and anaerobic digestion. In each instance, it is technological developments that have made these new forms of renewable energy feasible.

Mini Case: Solar power

While the sun has always been available as a source of energy, the means to transform it into a usable form is a comparatively recent development. To turn the rays of the sun into a usable form, i.e. electricity, relies on the photovoltaic effect. This was discovered by the French scientist Edmond Becquerel in 1839, but it was not until 1883 that an American engineer, Charles Fritts, built the first practical photovoltaic (PV) cell (Harford, 2020). This early form of solar power was expensive and inefficient and of little practical value. It was not until 1954 that researchers at AT&T's Bell Labs in New Jersey made a significant breakthrough when they noticed that when silicon was exposed to sunlight, it was capable of generating electricity and this had one great advantage – silicon was relatively cheap as well as being very much more efficient.

Despite this breakthrough, silicon PV cells were not a practical proposition as far as mainstream power generation was concerned. However, they did offer scope for generating very small amounts of power in very specialist applications. One such application, where only a very small amount of power was required was in the US space programme. Weight ruled out the use of batteries and cost was no object. Thus, it was that six small solar panels generating a mere half a watt of power were fitted to the Vanguard 1 satellite when it was launched into Earth's orbit in March 1958. This was the first time PV cells had been used as part of specific project (Goodall, 2016).

By the mid-1970s, the performance of solar panels comprising PV cells had improved to the point where they cost about $100 to generate one watt. But this still meant it would cost $10,000 to power a single light bulb. Fortunately, the learning curve has resulted in a steady fall in the cost of solar panels while their efficiency has continued to rise. By 2016, it cost a mere 50 cents to generate a watt of electricity from solar power. Today, in the sunnier parts of the world, solar power is competitive with power generated from fossil fuels for the first time. Even in the UK, the fall in the price of solar panels has meant that solar power is very nearly as cheap as electricity from gas-powered power stations.

Source: Goodall (2016); Harford (2020).

New forms of organization

New or at least different forms of organization typically cover changes to the internal structures used by businesses to conduct their activities, although as we shall see, it can extend to the introduction of different relations between businesses where two or more businesses wish to co-operate in some way in order to provide goods or services. An innovation in the form of a new or different form of organization would thus involve a business switching to a different internal structure for organizing and operating its internal activities. This is likely to involve a significant alteration to the organization of its value chain.

An instance of an innovation embracing a different form of organization would be changing from a unitary or U-form structure to multi-divisional or M-form structure (or vice versa). The former comprises a structure where the business is organized or managed as a single unit on functional lines, i.e. single departments such as marketing, finance and human resources. This type of structure emerged during the nineteenth century as large businesses such as railways began to emerge. It provides scope for specialization while at the same time coping with complexity. Henry Ford, for example, initially organized the company bearing his name in this way in its early years. The M-form structure, in contrast, involves organizing the business as separate divisions, each with its own semi-autonomous functional departments. One of the pioneers of this type of structure was Alfred P. Sloan, the chairman and chief executive of Ford's great rival, General Motors. Under Sloan, General Motors was divided into divisions each responsible for a specific brand of car such as Chevrolet, Buick or Oldsmobile. With this type of structure, operational control rests at the divisional level, which is responsible for financial performance. The M-form structure was widely adopted by large businesses in the years after the Second World War, enabling them to cater for a wider consumer base and increasingly differentiated tastes.

Another structural arrangement that businesses can adopt is to outsource some of their activities. Businesses that undertake all their production or service development activities themselves are said to be vertically integrated. They will carry out all the value-adding activities that form the value chain in-house. Henry Ford and the Ford Motor Company he established provide a classic example of a vertically integrated business. Keen to provide the highest possible control of his operation so that he could minimize delays, bottlenecks and hold-ups, his River Rouge plant in Detroit embodied his idea of an integrated operation under which the company not only assembled cars and manufactured the components required, it even produced the basic raw materials for car production such as steel.

Recently, the structural arrangements associated with vertical integration have been abandoned. Instead, businesses have increasingly resorted to vertical disintegration through outsourcing. The automotive industry provides a good example of the pursuit of outsourcing, as car manufacturers increasingly focus on car assembly and rely on external suppliers (termed tier 1, tier 2 suppliers etc.) to provide them with components. This even extends to the supply not just of components but whole modules such as engines, transmissions, instrumentation and upholstery. Another industry that has recently opted for increased reliance on outsourcing is aerospace. Whereas 40 years ago, Boeing produced something like 90 per cent of its best-selling 737 airliner in-house (this excludes the engines, which on almost all aircraft are obtained from a third party), its latest offering – the 787 – incorporates a little over 30 per cent produced in-house.

Another type of organizational innovation is the use of co-operative arrangements between companies. Generically termed strategic alliances, these can take various forms. Typical is the joint venture. This is an organizational form created when two separate and independent businesses decide to jointly undertake an activity, by setting up a new company that is jointly owned between them. The new venture will be independent of both in the sense that it has a separate legal status, its own staff and its own management with whom operational control of the business will rest. However ultimate oversight and control will rest with the owners in the form of the two businesses that desire to co-operate.

An example of an organizational innovation of this type is the aero engine manufacturer CFM International. It is jointly owned by General Electric of the USA and France's Safran Aircraft Engines. It was established in 1974 and at the time, represented a significant innovation for both companies. It was intended to enable both companies to gain a foothold in the commercial aero engine market, which at that time was dominated by Pratt & Whitney of the USA. It ultimately proved highly successful with its CFM 56 and Leap engines, which between them are the best-selling commercial jet engines of all time.

Degrees of innovation

As well as focusing on applications to differentiate innovations, there are other approaches to analysing the extent of innovation through some form of categorization (Dodgson et al., 2008). One widely used approach is to focus on the degree of novelty, or to put it another way, the extent of 'newness'. The advantage of using this sort of categorization is that it brings the extent of the change involved in an innovation into sharp relief. One focuses on just how new an innovation is, which in turn highlights the technological effort associated with an innovation. Quite literally, one is examining the 'innovativeness' of an innovation. In an era when lots of things are described as innovative, this kind of analysis can help to qualify such terms and enable judgements to be made about the degree of change embodied in an innovation.

It has long been noted that innovations vary greatly, from those that are completely new and different from anything that has gone before to those that involve little more than 'cosmetic' changes to an existing design. In the first instance, the degree of novelty would be high while in the latter, it would be very low. This distinction between big-change and small-change innovations has led some to a categorization of innovation that differentiates between radical and incremental (Freeman, 1974) innovations. In this categorization, innovations involving major breakthroughs, new technologies and major scientific advances would be in the radical category. More modest innovations involving product improvements that result in changes to product attributes, such as small improvements in performance or greater functionality, rather than new products, would be in the incremental category.

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. It often fails to show where the novelty really lies. To cater for this, Henderson and Clark (1990) have developed a more complex and more sophisticated analysis. This incorporates the concepts of radical and incremental innovation within a broader framework. Henderson and Clark's (1990) analytical framework allows us to analyse a range of innovations in more detail than simply classifying them as radical or incremental and predicts their impact in terms of both competition and the marketplace. The analysis does have its limitations, most notably that it is very product-oriented, though it can be used for service and process innovations. But it does at least help to show the sheer range of things that can be covered by the term innovation and importantly, it helps to focus on where the novelty in an innovation really lies.

At the heart of Henderson and Clark's (1990) analytical framework is the recognition that products, services and processes 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.

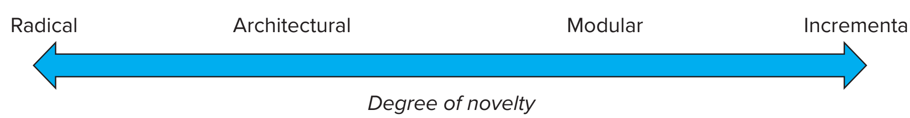
Henderson and Clark (1990) point out that to make a product, service or process normally requires two distinct types of knowledge:

1. *Component knowledge*, that is, knowledge of each of the components that perform 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 components.
2. *System knowledge*, that is, 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.

Henderson and Clark (1990) use the distinction between component and system knowledge to differentiate four categories or types of innovation (Figure 1.4). They use a two-dimensional matrix where one axis relates to components and component changes, while the other relates to linkages between components (i.e. system architecture) and changes in those linkages.

In this analysis, radical and incremental innovation are polarized as being at opposite extremes, where the former involves changes in components and system architecture while the latter involves small changes in components that enhance component performance. Against this background, the analysis introduces two intermediate types of innovation between these two extremes (Table 1.3, see next page), namely modular innovation and architectural innovation.

Figure 1.4 Typology of innovations



Radical innovation

Radical innovation is normally the result of a major technological breakthrough or the application of a new technology. Unlike incremental innovation, where each innovation typically draws heavily on what has preceded it, radical innovation is non-linear and discontinuous, involving a step change from what has gone before. Hence radical innovation is about much more than improving an existing design. A radical innovation calls for a whole new design. In Henderson and Clark's (1990) terminology: '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.' This new architecture, with new components linked together in a different way, often results from the introduction of a new technology. In some cases, this will be a transforming technology, which brings a different set of priorities into play both in the market and in the industry. Thus, in terms of the degree of novelty, radical innovations involve a high level of novelty because they employ a new design with new components integrated into a new system architecture. A radical innovation may well involve the use of a new business model, as when Haloid (later Xerox) introduced the electrostatic copier. In short, with radical innovation, just about everything changes.

Table 1.3 Changes associated with the degree of innovation

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

The flat-screen TV is an example of a radical innovation. What makes the flat-screen TV a radical innovation? Prior to its introduction, TVs and computer monitors utilized a cathode ray tube (CRT) to display an image. Compared to a TV utilizing a CRT display, a flat-screen TV incorporates a completely different technology, namely a liquid crystal display (LCD). LCD technology, which has its origins back in the 1970s, operates on entirely different principles. The LCD uses liquid chemicals whose molecules can be aligned precisely when subjected to an electrical current. First used for pocket calculators and wristwatch displays, LCD technology owes nothing to CRT technology. Compared to a CRT-based TV, the system architecture is different as are the components. Thus the flat-screen TV represents a discontinuous change rather than a linear one. CRT displays benefitted from a string of linear innovations over many years that improved their display characteristics but the introduction of the flat-screen TV represented a break with CRT technology. The net result is a product that has to be manufactured in a completely different way, rendering CRT manufacturing facilities and the knowledge surrounding them redundant.

Most radical innovations employ a new technology. Typically, it is much more than mere tinkering to provide an improvement in performance. Radical innovations represent a radical break from the past, with a new technology working on new principles to give new product characteristics. To bring the new technology to market is a huge task, with a high degree of uncertainty. Will the technology work? Will it provide products or services with characteristics that consumers want? Thus, radical innovation is both difficult and risky.

Radical innovations are, however, comparatively rare. Rothwell and Gardiner (1989a) estimated that at most about 10 per cent of innovations are radical. However, they tend to have more dramatic consequences than other types of innovation for the organizations that develop them. Typically, a radical innovation will require an organization to ask a new set of questions, to draw on new technical and commercial skills and employ new problem-solving approaches (Henderson and Clark, 1990). The jet engine provides a good example of a radical innovation that had far-reaching consequences in terms of organizational capabilities. Compared to its predecessor, the piston engine, the jet operates on quite different principles. Among the problems it presented were the need for new materials that could withstand very high temperatures. In terms of technical skills, it required a knowledge of aerodynamics. Nor did it stop there, for the jet had very different things to offer potential customers (i.e. commercial airlines), namely speed and smoothness.

Mini Case: The Intel 4004 Microprocessor

Unlike 1066 or 1492, 1971 is not usually recognized as one of history's most significant years. But it was in 1971, near San Francisco, California, that the American computer company Intel launched what was to prove one of the most radical innovations of all time – namely, the 4004 microprocessor.

The story had begun a couple of years earlier when the Nippon Calculating Machine Corporation approached Intel to design 12 custom chips for the new electronic calculator it was developing, the Busicom 141-PF. Intel's designers suggested that it might be possible to combine a number of the chips to reduce the total number required from 12 to 4. This would not only reduce the number of chips that had to be produced, but one of the four chips would be capable of being programmed so that it could be used in other products. The programmable chip would form a central processing unit (CPU). This was the first time anyone had combined all the functions required for a CPU on a single chip. Called the Intel 4004, it was the world's first microprocessor. This revolutionary microprocessor was the size of a fingernail and contained 2,300 transistors when first shown to the public in November 1971. It possessed the same computing power as the first electronic computer, which filled an entire room.

The 4004 chip found uses well beyond calculators. It unleashed a technological revolution. It formed the basis of the first personal computers (PCs) and its descendants power a significant proportion of the millions of PCs in use around the world today. Nor is its influence confined to computers. Microprocessors like the 4004 form the basis of smartphones, tablets and a host of other electronic devices. However, microprocessors have become steadily more powerful. The Intel core processors of today, which are direct descendants of the 4004, contain more than 500 million transistors.

Source: Intel (2014).

Because different organizational capabilities are often required with radical innovations, it is not unusual for them to be launched not by existing players in an industry but by new entrants. The iPod is an example. Working on different principles from earlier audio players, it provided an opportunity for a new entrant, Apple Computer, to enter the market. Apple was not at a disadvantage because the technology of MP3 was new and the existing firms did not have many years of accumulated experience to draw on. Nor is this a one-off example: we saw earlier how a radical innovation, electrostatic copying, provided an opportunity for Haloid (later renamed Xerox) to enter the market very successfully.

The concept of radical innovation is closely linked to Christensen's (1997) notion of 'disruptive technologies'. By 'disruptive' he means inducing significant changes in markets and industries, often leading to high levels of uncertainty. In terms of markets, these changes might mean completely new markets or new customers or new products/services. In industry terms, the changes often mean the arrival of new entrant firms better able to marshal the necessary organizational capabilities now required, and the departure of existing firms.

Thus, radical innovation typically has much more far-reaching consequences than any other type of innovation. The changes that accompany radical innovation often lead to periods of considerable uncertainty, perhaps with competing designs and increased competition. Eventually, however, as we shall see in the next chapter, this state of uncertainty subsides and radical innovation is followed by successive incremental innovations.

Incremental innovation

Incremental innovation involves modest changes to existing products/services (or processes or other forms of innovation) to exploit the potential of an existing design. The changes are typically improvements to components, possibly the introduction of new components, but always within the confines of an existing design. However, it is important to stress that these are improvements, not major changes. In other words, the level of novelty is low. Christensen (1997) defines incremental innovation as 'a change that builds on a firm's expertise in component technology within an established architecture' and this highlights an important feature of incremental innovation, namely that it is typically the product of existing practice and expertise associated with an existing technology rather than the introduction of a new technology.

Incremental innovations are the commonest type of innovation. Gradual improvements in knowledge and materials associated with a particular technology lead to most products and services being enhanced over time. These enhancements typically take the form of refinements in components rather than changes in the system. The technology is improved rather than replaced. Thus, incremental innovation is something that occurs quite frequently to create an essentially linear process of continuous change. The changes exploit the potential of an existing design using an existing technology. Thus, a new model of an existing product (perhaps described as a 'mark 2' or new and improved version) is likely to leave the architecture of the system unchanged and instead involve new components or refinements to components. In the case of the automatic washing machine (see mini case below), incremental innovation describes the way in which manufacturers have improved the efficiency of the machine by fitting more powerful motors to give faster spin speeds. With the system and the linkages between components unchanged and the design of the components reinforced (through refinements and performance improvements), the changes amount to 'incremental innovation'.

The impact of incremental innovation in terms of markets and industries is likely to be quite different from radical innovation. Incremental innovation, by using existing technology and the knowledge and expertise associated with it, tends to reinforce the position of incumbent firms. Similarly, in terms of markets, one is typically talking about increasing market penetration or entering new market segments rather than the creation of new markets. Thus, incremental innovation favours existing players. They are likely to be the ones with an established stock of knowledge and expertise in a given technology. In that sense, they will probably be the ones best placed to generate a steady (i.e. linear) stream of incremental innovations.

Mini Case: Automatic washing machine

The modern automatic washing machine is the product of a variety of innovations. The washing machine is a system for washing clothes. The components comprise: motor, pump, drum, programmer, chassis, door and body. These components link 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 greatly affected by incremental innovations. 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. In the mid-1970s, automatic washing machines typically had a maximum spin speed of 700 rpm. In 1976, Hoover launched its A3058 model, which boasted a maximum spin speed of 800 rpm. Two years later and Hoover's A3060 introduced a further innovation in the form of a maximum spin speed of 1,100 rpm. Since then, a steady stream of innovations has seen the speed rise to 1,200, 1,400, 1,600 and now 1,800 rpm. Although these advances have resulted in improved performance (i.e. drier clothes), the system has remained unchanged.

Among a host of other incremental innovations to have affected automatic washing machines have been changes in the washing temperatures, the amount of water they use, the amount of electricity they consume and the range of programmes they are able to offer. All this in a machine that looks pretty much the same as it did 40 years ago!

Modular innovation

Modular innovation uses the architecture and configuration associated with the existing system of an established product but employs a new subsystem comprising related and interconnected components that perform a specific function within an overall system.

As with incremental innovation, modular innovation does not involve a whole new design. Modular innovation does, however, typically involve a new and often very different design of subsystem, often utilizing a different technology.

New technology can transform the way in which the overall system operates, even though its configuration/architecture remains unchanged. Clearly, the impact of modular innovation is usually less dramatic than is the case with radical innovation.

The wind-up clockwork radio provides a good example of modular innovation. In the 1990s, before the introduction of mobile phones, many people in the Global South did not have access to radio because they lacked a reliable electricity supply. During the AIDS/HIV epidemic, this made the communication of public health warnings very difficult. To improve communication in these countries, inventor Trevor Baylis developed a wind-up clockwork radio that required neither batteries nor mains electricity. As a power source, it used a wind-up clockwork mechanism. The user was required to turn a handle that stored energy in a clockwork spring, which in turn powered a small electrical generator. In all other respects, it was a conventional radio. It not only provided those in the Global South with access to radio but also profoundly impacted the circulation of public awareness about HIV/AIDS.

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: 12) 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 will not be any 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, redesigned and reconfigured system.

An example of an architectural innovation would be the Sony Walkman cassette player. Amazing as it may seem, when it appeared on the market, it meant that for the first time one could listen to music on the move. However, the significance of the Walkman is not just that it met a hitherto unmet need. It also provides an excellent example of an architectural innovation. At the time, tape players were not new but what the Sony Walkman did was to repackage the components. In so doing, Sony changed the way in which the system was configured (i.e. the architecture into which the components fitted). The result was a much smaller and lighter machine and one that could be operated on relatively small torch batteries, thereby making it highly mobile. At the time, there were many in Sony who claimed that there was no market for such a machine. But Sony's boss, Akio Morita, was adamant. And he was proved right. It was a huge commercial success, selling 1.5 million units in just two years (Sanderson and Uzumeri, 1995). It was so successful that it was soon copied by other manufacturers. More significantly, it changed the behaviour of consumers. Young people found they could combine a healthy lifestyle while continuing to listen to music, so the Walkman may be said to have helped promote a whole range of activities like jogging, walking and use of the gym.

Case study: Teslafication

The automotive industry is going through what has been described as an 'epochal' shift as it moves away from the internal combustion engine and towards electric vehicles (EVs). At the same time, cars are making ever greater use of electronics and computers. Equipped with a blistering range of sensors, the electronic systems built into modern cars assist the driver in various ways ranging from safety to comfort and from navigation to engine control. In order to do this, cars require a multitude of computer chips and much greater reliance on software.

At the same time, there are signs that the trend towards ever-greater outsourcing by car manufacturers may be slowing. In some instances, it even appears to be reversing. For the last half century, car manufacturers have steadily outsourced more and more functions to the leading tier 1 automotive suppliers such as Bosch, Continental, Valeo and ZF. They, in turn, have been able to develop integrated systems or modules (e.g. transmissions, suspension and braking systems and instrumentation) rather than just components. With similar modules being sold to several car makers, the tier 1 suppliers use the resulting increased scale of operations to lower prices. The chief executive of the Italian-American car giant Stellantis, for instance, recently estimated that his organization's cars comprise as much as 85 per cent bolt-on (i.e. outsourced) parts.

One manufacturer, the German car firm Porsche, at one point even went as far as outsourcing car assembly. Between 1997 and 2011, the company outsourced assembly of one of its main product lines – the Cayman and its convertible sibling, the Boxster – to Valmet Automotive at Uusikaupunki in Finland. The logic behind this extreme form of outsourcing was that it provided valuable additional capacity in an industry prone to peaks and troughs in demand.

Vertical disintegration through outsourcing functions not only enabled car makers to focus on what they considered to be critically important activities like design, marketing, systems integration and management of the supply chain, it also freed up capital. However, there was a downside in that it often tended to put the car makers one step away from technological innovation. When the technological basis of the automotive industry centred on the internal combustion engine, much of the innovation was essentially incremental. With the switch to EVs, radical innovation is the order of the day. Under such conditions, technological innovation is paramount.

Hence car firms have begun to seek greater control over their value chain. This has extended from the minerals, such as lithium, nickel and cobalt, that go into EV batteries down to the software EVs run on and even the retail outlets where they are sold. Consequently, activities that were once outsourced are beginning to be brought in-house. Elon Musk's Tesla led this charge. His 'digger-to-dealership' approach embracing Silicon Valley's so-called 'full stack' model of internalizing most if not all aspects of production, is something other car makers are now beginning to explore.

By attempting to do everything under one roof, which is what vertical integration amounts to, Elon Musk is borrowing heavily from the past and from one individual in particular, namely the automotive industry pioneer, Henry Ford. Way back in the first half of the twentieth century, Ford's River Rouge plant in Detroit, Michigan utilized rubber for tyres from Ford-owned plantations and steel from Ford-owned ore mines and blast furnaces. The River Rouge plant inspired Ford to take a similar approach in the UK. When a site for a new manufacturing plant in the UK was being planned in the 1920s, Ford chose Dagenham in Essex, precisely because it offered the prospect of a deepwater port that would allow for bulk deliveries of coal and steel.

Meanwhile, a century later, Elon Musk's Tesla has recently brokered deals with suppliers of lithium and graphite to provide raw materials for its so-called 'gigafactories', producing batteries, such as the one opened in 2017 in the state of Nevada, owned and operated in conjunction with the Japanese electronics firm Panasonic. Early in 2022, Tesla also concluded a deal with the Brazilian mining giant Vale to supply it with nickel. Musk told the *FT Future of the Car* conference in May 2002 that Tesla was even considering acquiring mining companies in order to secure future supplies of rare metals like lithium required for battery production. He said, 'It's not out of the question … if that's the only way to accelerate the transition, then we will do that.'

Moves to consolidate and control the supply of raw materials for key parts of an EV, like the battery, are only part of the story. Tesla has pulled back in-house various aspects of car production. It now manufactures its own electric motors and a lot of the complex electronics. Tesla even designs its own semiconductors (i.e. computer chips) and, according to a recent report in *The Economist,* has developed closer links than other car makers with the firms that actually manufacture the chips. According to Dan Levy of the bank Credit Suisse, this gives the company significantly more control of key aspects of car production.

Source: The Economist (2022).

Questions

1. What form of innovation does 'Teslafication' involve?
2. What is meant by the term outsourcing?
3. In what ways has the automotive industry been outsourcing activities in recent years?
4. To whom have the major car makers outsourced parts of the car manufacturing process, and why?
5. Where did Porsche outsource assembly of its Cayman and Boxster models to and why?
6. From whom does Elon Musk appear to be borrowing ideas about the organization of car manufacturing?
7. What is the 'digger-to-dealership' model?
8. What benefits does Tesla get from its increasing use of vertical integration?
9. What are computer chips and why are they being used extensively in modern cars?
10. What factors have led to car makers' increasing involvement in the design and production of computer chips?

Questions for discussion

1. What is the value of differentiating different forms of innovation?
2. Why have we seen an upsurge in service innovations over the last two decades?
3. Which of Schumpeter's five forms of innovation do you think tends to have the greatest impact on society, and why?
4. What is a business model innovation?
5. Name three examples of supply innovations and explain their significance.
6. What sort of innovation is outsourcing and why?
7. What is the value in differentiating between different forms of innovation?
8. Choose an everyday object with which you are familiar (e.g. an electric kettle) and identify some of the incremental innovations that have taken place.
9. Why are only a small proportion of innovations typically radical?
10. Differentiate between component knowledge and system knowledge.

Exercises

1. Using any household object of your choice (e.g. vacuum cleaner, hairdryer) identify and analyse the following:
   - system function
   - components
   - system linkages
   - incremental innovation.

   Outline what you consider to be the rationale behind **one** recent incremental innovation.
2. What is meant by the term 'creative destruction'? Which of Schumpeter's five forms of innovation is it most likely to be associated with and why?
3. Anaerobic digesters turn waste food and other organic material into biogas. Investigate what biogas is used for and explain why it represents an example of supply source innovation.

4. 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 and (b) architectural innovation.
5. 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.

Further reading

1. **Harford, T.** (2020) *Fifty Things That Made the Modern Economy.* London: Little, Brown. A good starting point that gives details of some significant innovation.
2. **Schumpeter, J.** (1934) *The Theory of Economic Development.* Abingdon: Routledge, 2021. This is where it all started. 90 years on it is still the best academic overview of the subject. A particular feature of the book is the way it outlines the various different forms that innovation can take.
3. ***The Economist*** (2022) 'The great Teslafication', *The Economist,* 18 June, pp. 61–63. A recent article that demonstrates how innovation is about much more than new products. It particularly emphasises some of the organisational innovations currently taking place.
4. **Toivenen, M. and Tuominen, T.** (2009) Emergence of innovations in services, *Service Industries Journal,* 29(7): 887–902. A reminder that innovations in services are of increasing importance today. It provides some valuable insights into the features of service innovations.