2 - Technology Innovation and Adoption

Technologies are always constructive and beneficial, directly or indirectly.

Yet their consequences tend to increase instability.[1]

The development of new devices through invention and innovation has been the subject of many studies from the perspectives of engineering, sociology, anthropology, philosophy and economics. There is a wealth of literature on this topic that can be examined to provide the reader with an understanding of these developments. This chapter will examine some of the more basic tenets of technology development, innovation and adoption. While an effort has been made to ensure that the topics covered here are relevant, there does need to be some examination of the theoretical assumptions that are inherently involved in technology adoption.

The goal of the Shared Technology Project is to look at the future adoption and implementation of a range of established technologies that are likely to impact on the Shared Technology industries. These industries include the automotive; building and construction; engineering, electrical, electronics, information technology and telecommunications. The technologies identified primarily relate to the transfer of information through electronic means as well as the generation of electricity to power such devices.

This review of the process of technology adoption will focus on the more tangible aspects of technology using more of an economic-based approach than a cultural or sociological approach. The reason for this is that this project is focusing on the likely impact of technology adoption in the short term and on an adoption that will be based upon "rational" decision making processes within a commercial environment.

The use of examples is limited as the goal of this review is to outline the general concepts without providing conveniently placed evidence to support the theories. Some examples are used but the reader is directed to more lengthy reviews elsewhere where many examples are used.

Revolutions in Science and Technology

In the early 1960s, Thomas Khun published a critical work of the history of science and how changes in basic scientific theories are accomplished. This work, *The Structure of Scientific Revolutions*, initially received a cool response from those individuals who were perhaps the target of his criticism. However some years on from this publication, Khun's work remains widely adopted and relevant. It is especially relevant for our review of the adoption of technology as there are a number of similarities between scientific discovery and its acceptance by the science community and new technological innovations being accepted by the general community.

One of the terms that Kuhn uses throughout his essay is the term "paradigm". The word paradigm refers to a pattern or model and Kuhn has used it as the "accepted examples of actual scientific practice [that] provide models from which spring particular coherent traditions…"[2] These accepted models require new entrants to adhere to the existing knowledge structure. Paradigms also allow those who are fully involved in the area to be supported by peers when they adopt these recognised practices.

Minor adjustments in the knowledge base are welcomed as this provides the impression of progress. However if an individual were to deviate from these accepted norms and cause the accepted theories to be threatened, the community in which that individual operates will strongly protest. An example of such a change can be seen in Copernican astronomy that suggested that the earth revolved around the sun and this was a serious threat to the established Ptolemaic theory and also to the Catholic Church.

Kuhn describes these major shifts in conceptualisation as "revolutions" but these are more popularly known as "paradigm shifts". However most individuals use the term "paradigm shift" incorrectly as these paradigm changes are usually made through considerable discomfort, debate and restructuring. The application of this theory to the Shared Technology Project is that the likely changes in technology use in these industries will not be accomplished without some disruption to the traditional work processes and knowledge structures.

Terminology

There are a number of adjectives used to describe the types of technology that individuals encounter. In order to provide a theoretical framework for approaches in dealing with technology, writers have used a variety of terms to describe what is essentially the same idea. This multiplicity of terminology obscures the theory rather than simplifies it.

Technology – New and Old

The use of the term "technology" is also described as "the process of transforming basic knowledge into useful application. Science may be thought of as *know-what*

and technology as *know-how*."[3] In this project, the term "technology" is being used those new technical innovations that are likely to be shared across a range of industries where such use has not previously been evident. For example, the use of networked computers is not a "new" technology for the information technology industry but the application of a packet-switched network within electronic instrumentation in process and manufacturing automation may be considered to be "new" to those in these industries.

When we think about "technology" and use this term, we are often applying it to something that is new and attracts our attention. "Old" technology such as the wheel is not really considered to be technology as it does not change the way that we do things nor do we read journal articles about new uses of the wheel except for perhaps in microelectromechanical integrated circuits. Therefore "old" technology is all around us as is the air we breathe. We do not usually describe air as containing so much nitrogen and oxygen but more generally using terms such as of clear or hazy. The focus here is what is new and different.

Continuous, Cumulative, Sustaining and Incremental Technologies

These technologies are the result of changes brought about through the need to refine a particular aspect of a design to more closely fit a purpose such as reduce cost of production or meet a specific, local requirement. Alternatively the changes to the design may be as a result of the desire for differentiation with no functional purpose. It is these types of changes in technology that are more likely to occur than a revolutionary change or the development of some new exploitation of the physical world.[4]

These types of changes are more easily described as tinkering with existing technology and are less risky and costly than developing an entirely new process for which market acceptance may be difficult to manage. However for those individuals who have not experienced an existing technology, the changes occurring from this new application may seem discontinuous. The application of the technology may seem to be discontinuous but the technology itself is not. Therefore it is the situation that makes a technology appear discontinuous rather than any fundamental change in the technology itself.

Discontinuous and Disruptive Technologies

Few innovations today are actually discontinuous where the device utilises a previously unutilised aspect of physics. Examples of discontinuous technologies are Samuel Morse's telegraph, Guglielmo Marconi's radio or John Atanasoff's electronic computer. Each of these devices were exceptional in their development and had no apparent predecessor upon which one could compare their value.

In these cases, discontinuity appears surprising and initially unbelievable as did Copernicus' theory of astronomy. Not only are issues of scientific verification required but cultural and social values are also applied to the value of the use of a particular discovery. It is the value placed on these discoveries by a society that determines if the technology will be used.[5] These types of technologies are disruptive in terms of how a society or culture will deal with the issues of acceptance as well as the resulting changes in behaviour that are necessary to utilise the technology. Genetically modified food is one such technology that is

currently being debated. When electricity was introduced for lighting within the home some individuals commented that it was "elec-trickery", a health hazard or against nature.

Some reviewers of the development of technology have commented that there are really no discontinuous technological discoveries but that each apparent technology discovery was in Thomas Kuhn's words, "at least partially anticipated during a period when there was no crisis."[6] In this sense the revolution occurred before the technological application of a thought or theory and was before the "discovery" of the concept. For an example of one such case, please see Box 2.1 – The Development of Wireless Transmissions.

BOX 2.1 – THE DEVELOPMENT OF WIRELESS TRANSMISSIONS.

Radio communications are based upon the theory of electromagnetism developed by James Clerk Maxwell between 1854 and 1879. This work was a summary of what was known at that time of electricity and magnetism and included Michael Faraday's theories about the existence of magnetic and electric fields. Maxwell did not believe that he had to make a practical demonstration of his theory as it was mathematical and therefore an abstract concept. Practical demonstrations were considered by Maxwell to be unnecessary he and dismissed Alexander Graham Bell's telephone as being able to have been assembled by an amateur.

In 1887, 23 years after Maxwell's initial work, Heinrich Hertz demonstrated the existence of electromagnetic waves using basic equipment that was likely to be available within Maxwell's own laboratory. Hertz developed a basic transmitter and receiver but was not interested in wireless communications but in proving Maxwell's theory. About that same time, Sir Oliver Lodge was doing similar work and built a device similar to Hertz but did not recognise the ability of this force to send messages.

In 1892 the physicist Sir William Crooks wrote an article suggesting that this newly discovered force could create a telegraphic system that needed no wires. Lodge began work on signalling systems and demonstrated in 1894 a transmission over a distance of 59 metres. Although Lodge recongised the commercial application of this technology, he remained a physicist and was more concerned with patent rights that limited the dissemination of knowledge.

Guglielmo Marconi began work on wireless transmissions in 1894 and tested these to nearly one kilometre in 1895. The following year, Marconi moved to England and patented the entire area for technical applications that could be based on the work developed by Maxwell and Hertz. Marconi did continue work on antennae design to which he could claim full credit. By 1901 Marconi had tested trans-Atlantic wireless communications and received the Nobel Prize for physics in 1909 for using the theoretical work of scientists to shape their ideas into a practical and useable system.[7]

Emerging Technologies

Emerging is a term often used to describe those technologies that are likely to create new industries or transform ones already in existence and include the incremental or discontinuous technologies described above. This term is applied to those technologies where:

- The knowledge base is expanding;
- The application to existing markets is undergoing innovation; or,
- New markets are being tapped or created.[8]

It is important to highlight that these technologies can be new innovations or can be new to industry. In this Shared Technology Project, most of the technologies are already commercial realities and therefore will not be new to the industry in which the technology originates but new to the industry with which it is being shared.

Innovators, Society and Youth

George Homans reviewed the innovations of craft workers and suggested that the people who were most likely to create innovations were either those in power or those who had no power. Homans proposed that the higher classes produce innovations because they have the time, money and the desire to maintain and strengthen social and economic status. The lower classes have nothing to lose and everything to gain by creating an innovation. The middle classes were considered to be too busy working to think about inventing and that there is the possibility of a lower status as a result of a failed invention.[9]

Thomas Kuhn sees youth and inexperience as an advantage and states that it is usually the young or those new to the area of study who are able to provide new ways of solving problems.[10] While this statement applies to individuals it may also have an application for organisational development strategies. That is, it is sometimes easier to start an entirely new company that does not have the processes that may stifle creativity or prevent new ideas being raised.[11]

Theories of Change

There are a number of theories as to why new innovations are created. At the beginning of this review of technology and innovation, it was mentioned that the focus was on the commercialisation of technology and how it would apply to the economic realities of the industries being discussed. The theories outlined in this section relate only to those goals that are central for this project.

Natural Selection

Charles Darwin's theory of natural selection has been cited by a number of observers of technology adoption as a convenient method of describing what occurs. Darwin did not see his theory extending beyond the natural world and the application of his theory to the adoption of technology is a simile rather than an applicable explanation.

Darwin's theory of natural selection explains the diversity of life on Earth using an incremental assumption that a profitable variation in a living organism will allow the organism to find more food and therefore be more able to reproduce. "The theory of natural selection is grounded on the belief that each new variety…is produced and maintained by having some advantage over those with which it comes into competition; and the consequent extinction with less-favoured forms almost inevitably follows."[12]

A translation of this theory into the world of technology has some similarities. A technology that meets a particular need will be reproduced by an enterprise because it is profitable to do so. The technology then gains ascendancy in the market place and so is widely adopted while less well adopted technologies decline. Darwin does speak of "wedges" (or niches) where individuals are able to

survive but not necessarily become a dominant species. This is also true of some technologies that have a particular application although are not widely used.

Profit

Jacob Schmookler uses a market theory approach towards explaining why new technologies are developed. Schmookler believes that inventive activity is started by individuals who believe that such action will provide them with wealth by meeting an obvious need rather than one that is latent. This belief was supported through an analysis of patents where it was shown that an increase in investment led to an increase in the development of new innovations after an appropriate time lag.[13] This approach for assessing the development of conditions amenable for innovation may not entirely explain how innovations come about. For example, there was no perceived problem with horses as a means to pull vehicles prior to the development of the automobile.

A refinement of Schmookler's view is that "the power to capture attractive profits will shift in the value chain to those activities where the immediate customer is not yet satisfied with the functionality of available products."[14] That is, if the product accomplishes everything that the customer requires, then there is no reason why there should there be an investment to enhance the technology. However if the technology does not do all that the customer requires, then investment and innovation will take place.

Military Planning and Pure Research

A review of the history of warfare will show that technological innovation has been as a result of the demand from military planners to counter and overcome perceived threats from enemies. In recent times, military planners have developed the truck and aviation industries and the flow through from this has provided the general community with these beneficial applications of technological innovation.

The US Defense Advanced Research Projects Agency (DARPA) is mentioned on a number of occasions in this project as having developed technologies that have flowed through into the wider community. Additionally, the research that was undertaken to send American astronauts into space through the American National Aeronautics and Space Administration provided a base for the development of the microprocessor. The technology that is developed for these military purposes often has a more pacific use than is originally intended.

Technology and Failure

When technology fails to deliver the intended result it sometimes does so catastrophically. These errors and disasters lead innovators to develop more appropriate products. One example of the development of innovation was that of the De Havilland Comet. This aircraft suffered a number of catastrophic crashes for reasons not recognised until extensive testing showed the existence of metal fatigue. This testing and innovation of aircraft design would not have been undertaken without the failure of the technology.

This concept has led to a number of technical innovations and has been enshrined as what is known as Murphy's Law. This "law" was enunciated by US Captain Edward A. Murphy when doing rapid deceleration tests on pilots in 1949. Murphy

said that "if there are two or more ways of doing something, and one of them can lead to catastrophe, then someone will do it."[15] This failure has led to the development of standarised plugs as well as the development of safety standards.

Fear of technology

Some individuals welcome the development of new devices and technology however some fear this development. One of the more famous references to the fear of new technology is the movement of Luddites in the early nineteenth century. This was an unorganised movement of individuals under the instruction of Ned Ludd who smashed hosiery-knitting equipment in Nottingham, England. The use of the term Luddite in modern usage carries with it the meaning of a fear technology and does not represent the original use of the term. The Luddites were actually protesting against unemployment, high prices of food and falling wages.[16]

A more formidable form of a fear of technology (or technophobia) is Eric Drexler's suggestion in 1986 that perhaps one day self-replicating nanobots would over take the Earth and have a negative impact on humanity.[17] This view represents the fear of the unknown and an unknown that is not worth knowing as it is likely to change our ability to control our own destiny. Some have seen technology with a mind of its own changing in accordance with its needs rather than the needs, desires and wants of humanity.[18] Others seem to be accepting and more fatalistic:

> Technology demands more, not less, human work to function, and it introduces more subtle and insidious problems to replace acute ones, nor are the acute ones ever completely eliminated; in fact, unless we exercise constant care and alertness, they have a way of coming back with new strength. We are on a treadmill that we can no longer dismount from. We cannot turn back to a wholesome past, if only because the past, while sometimes more decorous, was far messier than we realize or perhaps can realize.[19]

Other individuals have theories that the best technology is being withheld so that those companies who have market power are able to maintain this even though the new technology would provide benefits to the community. Some individuals see a conspiracy at work that will deny humanity of endless power sources. One such theory is that British Petroleum (BP) has developed a high efficiency photovoltaic cell but is keeping this hidden in order to sell more petroleum products. If this is the case, BP deliberately set out to loose millions of pounds on unnecessary research on this very technology.

Adoption Rates

Technology is adopted at rates that vary with each technology and application depending upon the culture and economic system at the time. However if each of these new technologies is mapped on a graph, there are some similarities. Two models are provided here. One is the classic description of the introduction of new products or the life-cycle of technologies. The other is a much newer model that views technology adoption from the level of public awareness.

Classic Model

The rate of adoption of technology is one of most well documented processes of technological innovation. In nearly every text on the subject there are graphs that compare the introduction of a range of technologies such as automobiles and telecommunications. From all of this documentation, there are a few theoretical models that have endured and remain current.

The first and most famous is the cumulative adoption rate for new products. With the introduction of new products, there is a long-standing assumption in marketing that the adoption of a product or service follows a predictable growth pattern at sequentially different periods during the product life cycle. This is represented in Figure 2.1 – Theoretical Adoption Rate for New Products / Services.

Figure 2.1 – Theoretical Adoption Rate for New Products / Services

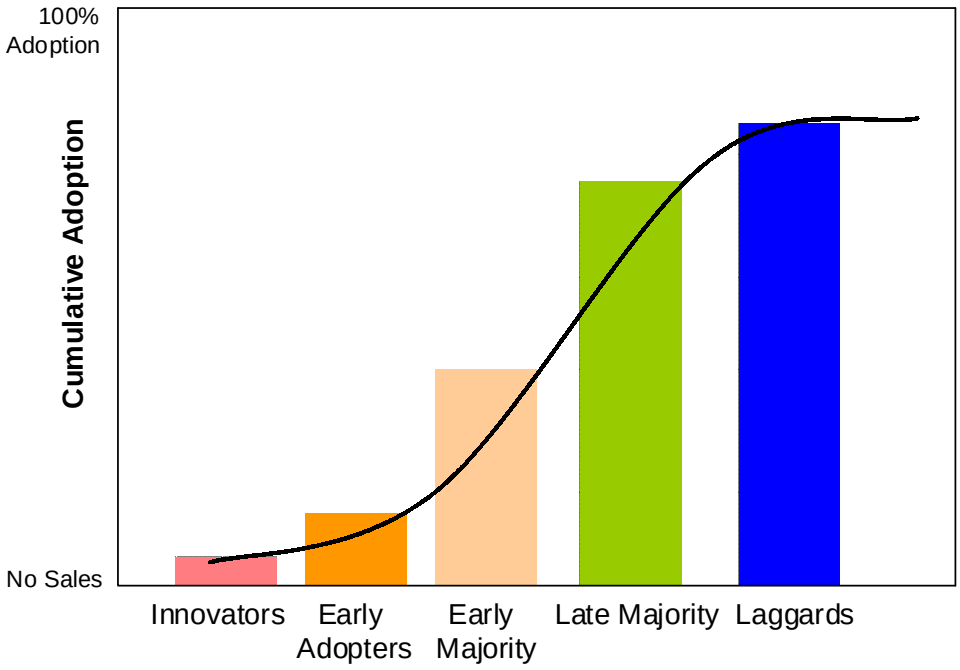


Figure 2.1 shows that during the introductory phase of a new product or service, there will be only a few consumers in the early stages. This is due to the initial high cost of the product or service itself as the developer wishes to attract those who are keen to "be the first". These individuals have sufficient funds to purchase the product or service at a high price that provides an early financial return to the developer.

As the product or service becomes better known, a slightly larger group termed "early adopters" begin purchasing. After this period other producers enter the market with competitive products and the "early majority" begin to purchase the product or service usually at a reduced price and with greater product or service offerings. As the market matures further, the "late majority" and "laggards" enter at the respective stages.

At this end point the product or service is mature, there are many players and competition is a main feature. Product improvements are made and new products

or services are introduced that begin the process again. It is important to note that even at the most mature stage, a 100% market adoption is not expected.

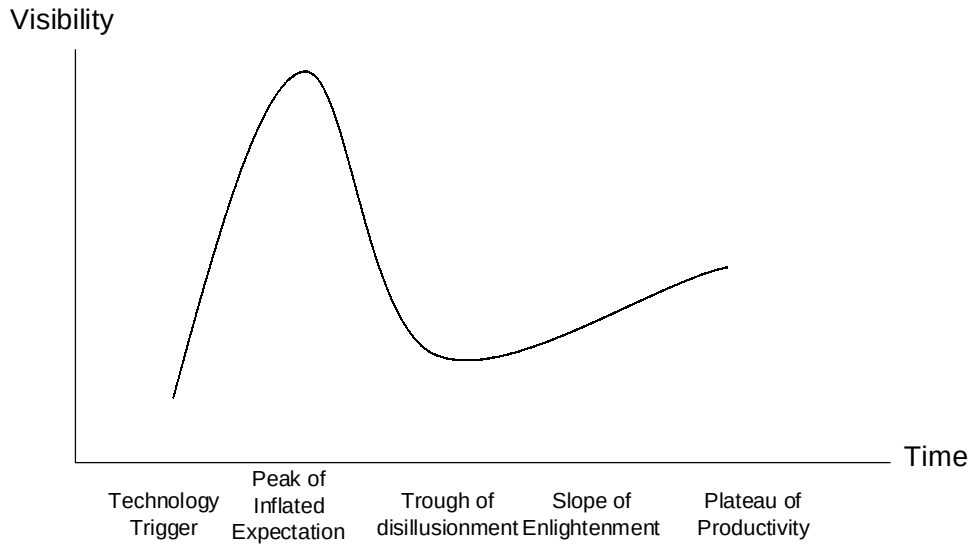
Gartner's Hype cycle.

The business consultant and research company Gartner provides a model for examining the diffusion path of new, emerging and disruptive technologies. This model is known as the "Hype Cycle" and assists in the identification of technologies that are likely to be adopted by industry and the community. The Hype Cycle was introduced by Gartner in 1995 and shows the path that technologies travel from invention, imagined applications, technical development difficulties and finally commercialisation. Figure 2.2 Gartner Hype Cycle is shown below.

The major descriptors for these stages are as follows:[20]

- Technology Trigger: A breakthrough, invention, discovery, public demonstration, product launch or other event that generates significant press and industry interest.
- Peak of Inflated Expectations: During this phase of overenthusiasm and unrealistic projections, a flurry of publicised activity by technology leaders results in some successes, but more failures as the technology is pushed to its limits. The enterprises that make money during this phase are generally conference organisers, magazine publishers and consultants.
- Trough of Disillusionment: Because the technology does not live up to its inflated expectations, it rapidly become unfashionable, and the press abandons the topic or touts its failure to meet expectations.
- Slope of Enlightenment: Focused experimentation and solid hard work by an increasingly diverse range of organisations leads to a true understanding of the technology's applicability, risks and benefits. Commercial off-the-shelf methodologies and tools become available to ease the development process and application integration.
- Plateau of Productivity: The real-world benefits of the technology are demonstrated and accepted. Tools and methodologies are increasingly stable as the enter their second and third generations. The final height of the plateau various according to whether the technology is broadly applicable or benefits only niche markets.

Figure 2.2 – Gartner Hype Cycle



Performance Rates and Inflection Points

The incremental rates of improvement in technological innovation are known as performance rates with each technology displaying a particular level of progress. The more famous rate of improvement is that of the microprocessor/integrated circuit which is described by Moore's Law that states that the number of transistors able to be placed on an integrated circuit increases every 18 months. There have been studies into these improvement rates for electricity generation and other technologies.[21] However it seems that these developments can not improve endlessly and that there will be a point at which improvement is either not possible or not necessary as the technology has been superseded.[22]

The points at which the rate of improvement or adoption of a technology changes is known as the inflection point and is demonstrated in Figures 2.1 and 2.2. The change in the rate of change provides signals to those who are considering investing in a particular technology. This is a similar situation to that of general economic activity with its assessment of interest rates, movement in share prices, bond prices and real estate.

Technological Progress

From the Renaissance to the present, there is a general belief that there are certain elements that describe technological progress. These are:

- Technological innovation brings about an improvement in the technology
- Advancements in technology lead to a betterment and growth in civilisation
- Progress in technology is able to be quantified

- The origin, direction and influence of technological change is controlled by humanity
- Technology conquers nature and brings it under human control
- Technology reaches its highest form in the Western, developed countries.[23]

This optimistic view of technology has been under assault in the last century as modern warfare does not necessarily provide for a betterment of civilisation. This description above also does not include the destructive aspects of global warming and other polluting activities. Therefore, not all new technology is beneficial and therefore some technological progress is not progress at all. This does provide some substance to the debate that technology is not within human control but it may perhaps be more correctly described as not being within humane control.

Summary

Technology may be adopted quickly or grudgingly by a society but it does so at particular rates that can be mapped within a number of models. The adoption will depend not only upon economic realities and benefits that are provided but also upon the social and cultural forces. Managers of enterprises and training providers will be able to assess the technologies described in this project using the models and theories provided. It is hoped that these assessments will lead to better decision making.

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