The technology adoption life cycle: Model building

By

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Abstract

This paper examines the various stages a technology may enter over its useful lifespan, and how companies might respond to various changes in the competitive environment. This analysis applies concepts from creative destruction and the product life cycle to generate a five-stage technology life cycle for technology adoption and commercialization. The proposed stages are: Pilot, Acceptance, Dominance, Abandonment, Specialization. This is followed by an examination how changes in item cost, usage cost, and intrinsic discount cost moves the technology to another stage. The paper ends with a discussion on how business decision might be improved by using the proposed model.

Keywords: Technology, adoption, patent, creative destruction, product life cycle, innovation, technology management

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Since the industrial revolution, industrialized nations have witnessed a frequent rise and fall of companies and industries as technology advances. This "creative destruction," as it was described by Schumpeter (1950), describes the frequent displacement of industry-leading companies by technological advances. A great deal of research focuses on how a new technology becomes successful in the marketplace, as well as much work analyzing the process of an incumbent's failure. Industry leaders using older technology often seek to find the right time to switch technology to remain competitive and relevant.

By comparison, there are less interests in finding uses for an existing technology after it has become less productive, or more importantly how to best extract economic benefits from an "obsolete" technology. A quick search on Business Source Complete in October 2018 yielded 6,465 peer reviewed articles that discussed "new technology," but a search for "obsolete technology" in the same session yielded only 16 results. How to maximize the value of older, mature, or obsolete technology would be of great interest to firms that have a significant stake with a more matured technology but are not involved in the delivery of the final product.

Many business management scholars recommend that companies invested in the more mature technology either adopt to the new technologies or exit the market. While how companies respond to different events should be answered on a case by case basis, the range of potential alternatives may not be available to companies that are part of the technology supply chain but not with the creation of the final product. For example, the choices for authors in responding to the electronic reading devices would be very different from the book publishers, or the paper mill suppliers. Some authors see the new reading devices as an opportunity to reach more readers. Some book publishers see the electronic media as a threat because the electronic media will diminish the sales of their printed books while other book publisher may view the electronic media as an opportunity for them to reduce its cost and increase profit. The paper mill supplier will now have one less outlet for their product due to the use of these electronic reading devices. Different industries will also have different responses to a technological shift. While the growth of the Internet has transformed many industries, not all industries are transforming in the same way. For instance, book stores have responded to the rise of e-commerce very differently than advertising agencies. Large book stores, such as Borders Books, were slow to respond to the rise of e-commerce from Internet and were too late to maintain their presence in the economy. However, social media, also an outgrowth of the Internet, were quickly embraced by advertising agencies which allowed them to stay relevant in their industry.

This article hopes to provide some guidance to decision makers by introducing a five-stage technology adoption life cycle model: pilot, acceptance, dominance, abandonment, and specialization. The analysis will center around three different end user costs: production cost, usage cost, and intrinsic discount cost, and speculate how these costs can affect the transition between stages of technology adoption. The discussion begins by reviewing prior works on technological change, specifically the body of knowledge on the theories of creative destruction, product life cycle (PLC), and the role of patent in innovation. After these grounding theories are presented, the paper will then introduce a five-stage technology adoption life cycle model with the end user cost analysis. After the characteristics of each stage are discussed, suggestions for future research are presented.

Before starting the review of relevant work, some clarification on the definition of technology. In this article, technology would be a controllable process that yielded a desirable characteristic. This desirable characteristic would be used in some product and there may be other processes that can yield a similar characteristic. For example, to brighten an area, one can set wood on fire, send electricity through a metal wire, or transfer light using an optical fiber from a lighted area to a dark area. Each process will provide luminosity, and each is a different technology. Alternatively, the engine for a car may be powered by internal combustion engine or electric battery to produce motion. International combustion engine is a different technology than electric battery. Thus, the car industry may utilize different technology for the same function. Which technology is best for the car industry or the lighting product at any one time is the focus of this analysis.

Additionally, depending on how broadly or narrowly the process is defined, it is possible that a technology can be applied to just one type of product, or it can be applied to a range of products. For example, photolithography technology is almost entirely used to etch semiconductors to make transistors. However, the semiconductors technology may be used to make a computer, phone, or a flashlight.

Relevant Work

Creative Destruction

Since the Industrial Revolution, the leading companies for many industries constantly change with the passage of time. Many scholars (DeHan, 2014; Ehrnberg, 1995) have credited Schumpeter for making the connection between innovation and this constant change and coining the term "creative destruction." For Schumpeter (1950), creative destruction was the result of a new process that better serves the needs of the consumer. Schumpeter argues that a capitalist society, by its very nature, cannot stop "mutating," or changing, in an attempt to increase efficiency and profit. By modifying a process or technology, a new business may be able to offer similar products at a lower price or satisfy the customer's needs better. Various scholars have improved on Schumpeter's Innovation Life Cycle. For example, DeHan (2014) has proposed that the three stages of innovation life cycle, radical innovation, important innovation, and pseudo innovation, would depend on the type of innovation associated that is worked on by individuals or companies. According to DeHan's discussion, one can interpret iPhone in 2007 is a radical innovation because these smartphones changed many people's live. Important innovation of smartphone occurred between 2009, about 170 million units was sold, to 2015, over 1.4 billion units sold in 2015. In 2016 and 2017, there exist pseudo innovation since there is a lack of major change in features for the smartphone. Unlike DeHan, who took an entire class of technology, or innovation such as camera or car engine as the unit of analysis, Ehrnberg (1995) uses each incremental advance in technology as unit of analysis. For DeHan, the changes in technology resulting in an increase size of integrated circuit wafers from 150mm to 200mm to 300mm is the same technology, whereas Ehrnberg would classify them as different technology. Hence, there exist differences in how technology is analyzed. The model introduced in this paper follows DeHan's version of technology analysis.

In describing the "creative" part of the process, Schumpeter observed that the pressures of competition will push many individuals, organizations, and entrepreneurs to make any given technology more efficient. Schumpeterian scholars believe that inevitably, an entrepreneur or existing company will succeed in creating a more efficient technology. A new business based on a more efficient technology or process will become more successful over time, eventually displacing firms that use less efficient technology.

The “destructive” part of the process comes when a company or product ceases to exist. As Schumpeter describes, this can occur when a leading company leaves the industry because of competitive pressure from a new technology and fails to adopt to it successfully. The potential impediments to adopt new technology are: the older technology may continue to generate economic benefit for a company; executives believe the older technology to be able to match the efficiency of new technology over time; investment to the older technology is not fully recovered, or executives expect to maintain market share with the older technology. Companies using the newer, more efficient, technology will experience an increased productivity. Companies not adopting to the newer technology will eventually under-perform, become less competitive, and ultimately be forced to exit the industry.

As an illustration, early televisions were made with vacuum tubes. When the transistor became widely available and affordable, televisions made with vacuum tubes became less desirable because of reliability and durability issues. Companies that continued to make television with vacuum tubes would have experienced declining sales. Eventually, this would force them to either begin making televisions using transistors, find a way to exploit some advantage of vacuum tubes over transistors, or exit the business.

The process of creative destruction has been researched extensively since the concept was introduced. Most research has assumed that once a newer technology created a comparable or superior product, any company using the older technology would be under stress. For example, Zinkhan and Watson (1996) applied the “creative destruction” concept to changes in marketing techniques. They argued that because of advances in communication technology, there is a need for marketing professions to leverage these newer technologies to reach potential consumers. Similarly, Belk (2014) illustrated the adoption of a “new” sharing business model and suggested that this “new” business model was more efficient because resource will be used by multiple users instead of just by one user. Lin and Chen (2007) identified that administrative technology / innovation has a big impact on a firm’s sales. These studies focus on the “creative” aspect of the process, but none took the next step of looking for the “destructive” part of the process. For Zinkhan and Watson, the decline in marketing communication through older communication channels is assumed, and whether marketing through radio, broadcast television, or cable television stopped entirely are not discussed. While, Belk (2014) did suggest that there may be some hurdles in implementing the new strategy, Belk did not address the destruction process with a discussion of a more fundamental question of why business would choose to own some common resources such as cars or buildings. Lin and Chen focus only on why Small Medium Enterprises (SME) should use radical administrative technologies but readers are left wondering if the disappearance of some SME is because they did not use the radical administrative technology.

There are limited efforts to examine the destructive side of the discussion. Using four cases, Clemons, Croson, and Weber (1996) argued that dominant firms that pursue low average price will more likely to fail when challenged by a newer entry that targets a niche that is less expensive to serve for the new player. Similarly, Gimenez (2006) used mathematical equations to model how cost-benefit analysis may trigger a change in technology. However, some products may be destroyed completely, such as vacuum tube television replaced by transistor television, other products such as DVD still retains a small market share even though how we watch video had two disruptions since 2000, first with Blu Ray then with video streaming. Here, forcing out of the marketplace does not equate to destruction.

Cooper and Schendel (1976) and Christensen (2003) have offered many reasons why industry leaders chooses to stay with an older technology. Cooper and Schendel (1976) indicated that firms employing the older technology are still making improvements, even when it is obvious that the newer technology excels in some niche and will stay relevant in the industry. Christensen (2003) suggested that often, the leading company of an industry is willing to give up some market segments to a newer technology because these market segments have a lower profit margin compared with their core businesses. However, if a leading company develops a newer technology, it faces questions about how to manage the innovation – what Christensen called the “innovator's dilemma.” For example, Kodak invented the world’s first digital camera in 1975. A little more than 25 years later, Kodak was not able to maintain its lead in the photography industry because taking picture using digital camera is not a business model that Kodak can use to make the same amount of profit as with the film business. In this case, Kodak’s dilemma would be: should they spend current resources, which would lower its profitability, developing the digital camera technology knowing that advances in digital camera will result in great financial pain in the future for the company.

Product Life Cycle

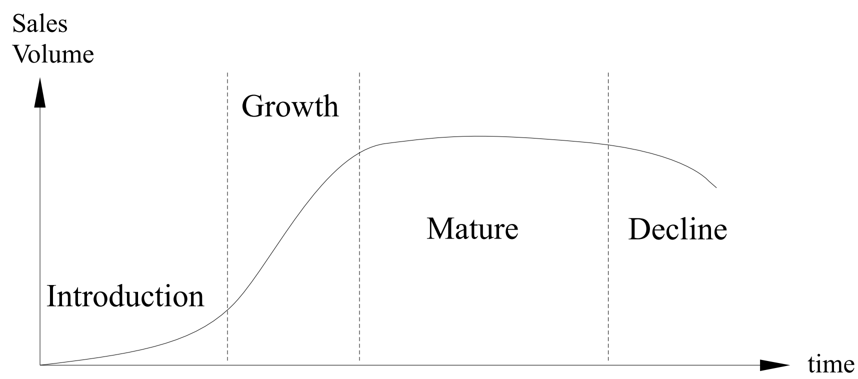

Figure 1: Product Life Cycle

The body of knowledge on creative destruction suggests that when a company chooses not to use the most efficient technology, they will eventually force to exit from the market. A similar conclusion can be inferred when examining the body of knowledge from the Product Life Cycle field, or PLC. The discourse in the 1960’s from scholars argued on the shape of the PLC curve. Brockhoff (1967) suggested an extended period of decline stage while Cox Jr., (1967) offered no less than 5 different curves for PLC. There were no less than 10 proposed curves for PLC by the 1970s (Rink and Swan, 1979). Most researchers today, however, accepted the Sigmoid curve or the S-curve when referring to PLC, with identifiable stages as: introduction, growth, mature, and decline (See Figure 1). The destruction of a product or industry can be inferred from the ending of the curve in the decline stage since business executives would stop producing the product or run the business when its sales falls below their break-even point.

Although PLC can assist executives to make decisions relating to the company's product, scholars and practitioners have indicated that PLC has various limitations (Christiansen, Varnes, Gasparin, Storm-Nielsen, and Vinther, 2010, Day, 1981, de Kluyver, 1977, Dhalla and Yuspeh, 1976, Polli and Cook, 1969). Some well-known limitations of PLC are: the stages of the PLC are not supported by empirical evidence (Levitt, 1965); PLC is more useful when analyzing an aggregated product group instead of an individual product (Christiansen et al., 2010, Dhalla and Yuspeh, 1976); time is just one of the factors that affect demand, while innovation or changes in technology often have more effect with demand (de Kluyver, 1977); the stages of PLC may not be occur in sequence (Christiansen et al., 2010); the PLC curve may not be as simple as Levitt suggested back in 1965 (Polli and Cook, 1969); and finally because of the above limitations, it is not always possible to determine what stage of the PLC is the product in at the current moment (Day, 1981).

Technology and Patent

There are many ways to assess the dominance of a technology, such as number of different variations of a product or number of units sold using the technology. These data, however, may not be accurate and may be subjective. They may not accurate because high likelihood of under-count as some smaller players may not be capture in the data collection phase. Since the likelihood of being included in the data collection would be those players that often makes the news, the data would be biased towards the well-known players. Counting patents filed would be used to assess the likelihood of dominance for a particular product since regardless of whether it is a small innovator or an established company's research effort, all would have to file with the United States Patent and Trademark Office to protect their intellectual property rights. Researchers can leverage this central data depot to analyze and test their hypothesis. Determining if a technology is the dominate technology or near the end of its life, one may compare the number of patents applied within a period to determine the level of interest for a technology. A dominating technology should have a higher level of effort to innovate and hence result in new patent filed. A technology that is at the end of its life would not have enough monetary incentive to innovate since some other technology is replacing it.

In need of improvement

While the two grounded theories, creative destruction and product life cycle, complements each other, the studies based on these two theories generally focus on the early part of the innovation process. Once the technology ceases to be "new," it is often ignored in subsequent analysis, even when research acknowledges the existence of older technology. Zinkhan and Watson (1996) used "creative destruction" as an argument to legitimize "hybrids" form of marketing. While the study identified radio, TV, and on-line medias as different forms of marketing, the fact that radio and TV marketing were not destroyed was not discussed. Other studies have suggested that manufacturing should "create" products to enter the service side of the business when the goods enter the mature stage of PLC (Gebauer, Gustafsson, & Witell, 2011). However, the use of the manufactured goods is expected to continue to exist, but the two grounding theories would suggest that the manufactured goods to be stopped.

Further, the idealized version of these two theories might assert that products such as bows and arrows, candles, and horse-drawn carriages should not exist now because these products were replaced by more advanced technology. However, even in an industrialized society, one can still find these products for sales or in use because the cost of ownership or usage is acceptable to some portion of the potential customers. At the minimum, this is an opportunity to formulate a set of life cycle stages for technology adoption that will address the anomaly of why some older technology continue to existence in the modern economy.

Model Description

From the literature review, one may formulate a five major stages of the technology adoption life cycle to explain how technology are used in modern economy. The five stages are Pilot, Acceptance, Dominance, Abandonment, and Specialization (see Figure 2). While not all of the technologies are expected to experience all of the proposed stages, just as not all products enter all of the PLC stages (Christiansen et al., 2010), a successful technology is likely to traverse through all of these stages

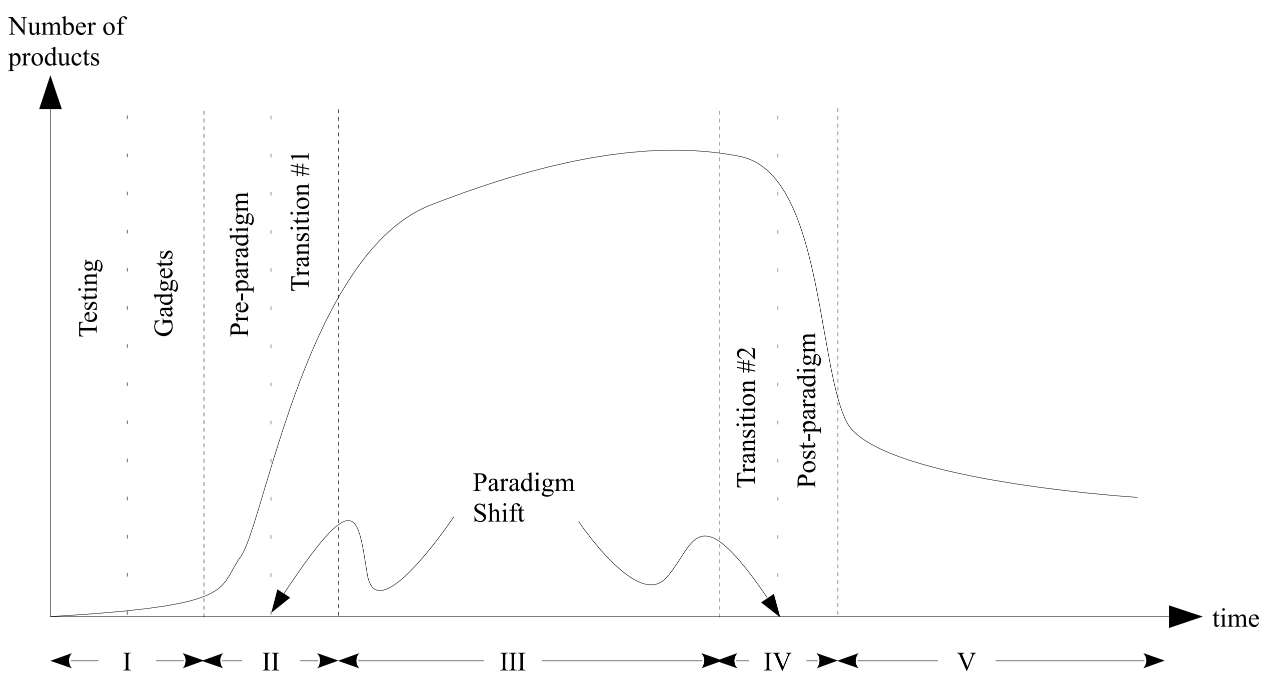

Figure 2: Technology Adoption Life Cycle

In the following discussion, "technology" refers to the current technology moving through the stages of the technology life cycle, while "older technology" refers to a dominating competing technology that the current technology is attempting to replace. The “newer technology” refers to a new competing technology that may or may not replace the current technology. The older technology would be the dominating technology when the current technology is still being researched or explored. For example, if an analysis on the time keeping technology is explored, and pendulum clock is the current technology, an "older technology" would be a water clock or solar clock, while an electronic or nuclear clock would be referred to as the "newer technology."

Stage I – Pilot

The first stage of this technology adoption life cycle, Pilot, contains two sub-phases: Testing, and Gadgets. The main characteristic of this stage is that the number of items or products created with the technology is negligible. All technologies begin at this small scale.

The first phase of the Pilot stage is Testing, during which research scientists and engineers explore the viability of the technology. Scientists and engineers are still conducting basic research on the technology, rather than exploring how it might meet any consumer needs. Because knowledge about this technology is limited and not widely disseminated, scientists and engineers need to test its basic effectiveness. The items created by the technology will be limited to the numerous experiments conducted by the researchers and engineers. Most likely, items or products with the new technology would not be sold and patent applications may not exist because the science or technology is not well understood during this stage.

Once there is sufficient understanding about the technology to enable a particular functionality, and such understanding is disseminated, the technology should enter the Gadget phase. Here, individuals and companies developing the technology in this phase are ones that wants to be first-movers, such as field engineers or hobbyists. Once the process of implementing certain functions using this technology is understood, these first movers would begin to create items using this technology to service their needs. The total number of items created using the technology would be higher than in the Testing sub-phase because one field engineer or hobbyist may try many iterations of items from this technology. As these field engineers and hobbyists show off their new creations with the technology, it can inspire other imitators. This process will create more items than the pure experiments conducted by the scientists and leading engineers; however, it would not be of comparable quantity as volume production.

One can posit that a difficult to understand technology will take a long time to get out of the Testing phase, while a technology that has a high capital requirement will take a long time to advance from the Gadget phase. It is possible that this technology adoption life cycle stage moves directly to the final stage, Specialization, when it can only service a specialized need well but fails to be competitive against the older technology.

As an illustration, the period during which Faraday experimented with the potential of using electricity to create motion would be the Pilot-testing phase. Subsequently, when more individuals conducted electric motor experiments, the technology would have entered the Pilot-Gadget phase. It would be reasonable to see products with the technology available for sales and some initial patent applications with government agency. Hence, the number of units sold and the number of patent applications in this stage would be relatively low or negligible.

Stage II – Acceptance

The second stage of technology adoption life cycle, Acceptance, contains two sub-phases as well: Pre-Paradigm Shift, and First Transition. The main characteristic for this stage is a steady growth in the number of items created by the technology. In the first phase, Pre-Paradigm Shift, a limited number of mostly new companies have assessed the potential of using the technology to create items that can service some functionality and began production. A prerequisite to the growth of production is a cost advantage of this technology over the older technology exist in some niche market. This paper will use three types of cost advantage, production, usage, and intrinsic discount advantages, to explain the dynamics in this stage.

The production cost advantage relates to a lower production cost for the manufacturer, and part of the cost saving have passed to the consumer, which is easily observed as the price of the item. This is a one-time cost for the consumer; that is, the consumer would spend less resources, or money, in the beginning to get the relevant needs satisfied. It is unlikely that this cost advantage alone would be sufficient to promote progression of the technology to the next stage of technology life cycle for two reasons. First, since the production process for the technology has just begun, the optimal production scale would not have reached the point where it is competitive with the production process that uses the older technology. Second, firms using the older technology have had time to reduce their production cost through refining processes and achieving economy of scale. Hence, from the user's perspective, the technology rates poorly on this metrics, such as cost per day, unit cost per size, or unit cost per use. For example, when the digital video disk (DVD) was first introduced, its cost per disk was higher than the compact disk (CD). However, over a period of several years, end users first noticed that cost per storage unit becomes comparable with the CD; then the cost of a DVD became comparable with a CD. This cost advantage, when observed, will entice end users to use DVD instead of CD as a storage media. A more likely scenario for the achievement of cost advantage that the technology can rely on may be absolute cost advantage; that is, on the scale that the need is to be satisfied, the product using the older technology has reached the limit of efficiency improvement.

To sustain a niche in the market, the technology would be more likely to rely on usage cost advantage which is often derived from some key feature of the technology. Features such as: the items created by the technology last longer, consume less resources during use, or have better safety features. Again, this can be observed by the consumer after purchasing an item created by the technology. However, since this cost advantage must be observed over a period, the end user must first be willing to try the item made by this technology. For example, the technology needed for the modern fluorescent light bulb has been around since the 1930s, and the fluorescent light bulb tends to consume less power and last longer. These two attributes allow the fluorescent light bulb to establish a niche in the market. The two attributes should also be important for the end users. Yet, the volume for fluorescent light bulbs was not able to overtake the incandescent light bulb until the cost of ownership fell significantly, that is, when the end user no longer needed to replace their existing lighting equipment and they can justify the lower cost by factoring in cost of usage and replacement. The power consumption of the fluorescent light bulb resulted in a usage cost advantage over the incandescent light bulb for the lighting industry.

The intrinsic discount cost advantage of the technology would be some attribute that is difficult for the older technology to duplicate. Such attributes may include speed, accuracy, power, weight, or some other important value-added attribute that satisfies a specialized need. For example, the speed offered by the airplane in the transportation industry is an intrinsic advantage over other forms of transportation. If a sales representative needs to be in Boston on Monday, Washington, DC, on Tuesday, and Orlando on Wednesday, with less than ten hours allocated for traveling because the individual does not want to sleep in a bed that moves, then the only way to achieve this goal is the use of air travel even if the cost of air travel would be more than the cost of travel by train or car.

Many incumbent companies assess these cost advantages differently. The incumbent companies may believe that production cost is the most important cost, when the users may have hinted that they have moved to another measure of cost. The incumbent company may also correctly determine that the technology does not pose a threat because of higher usage cost but do not monitor the development of the technology because they did not factor the intrinsic advantage that the technology provides. This would be when the “destruction” process begins, because many incumbent companies believe the technology offers no cost advantage over the older technology.

If there is no cost advantage, then the technology would move to the final stage, Specialization, and would not enter the First Transition phase. However, if the items created by the technology stayed at a certain level of demand, when a cost advantage is eventually found, a paradigm shift may yet occur. Once the consumer acknowledges that a cost advantage exists, the demand for items created by the technology should grow. Since supply will follow once demand increases, more capacity would be created.

The demarcation of the First Transition phase, or the first paradigm shift, is for the sale of items created with the technology to be greater than the sale of items that are created with the older technology in this industry. The number of companies that produce items using the technology may not be large because of patent protection or industry secrets. However, for the supply to increase quickly to meet the demand of the consumers, it is more likely that the number of companies employing the technology will increase quickly. Companies that made an investment on the technology during Pre-Paradigm Shift should be more successful in the First Transition phase than new entrants.

However, there are two possible ways for the technology to skip the Dominance stage entirely. One possibility is that the cost advantage experienced by the end user is only short term, and there is no cost advantage in the long term. That is, production cost may be lower, but cost the end users more due to higher maintenance costs, health hazards, or safety standards. If these costs are discovered before the technology enters the Dominance stage, the industry may reverse course and return to the older technology. The other possibility for a technology failing to enter the Dominance stage is that a newer technology demonstrates a better fit with the needs of the customer. In this scenario, the industry may experience two paradigm shifts in a short period. The technology from the first paradigm shift may enter stage four, Abandonment, directly. It is likely that the compact fluorescent (CFL) light bulb is experiencing the transition to Abandonment because a slightly better technology, light emitting diode (LED) light bulb, is gaining acceptances over CFL light bulb.

Since more units are sold in this stage, the innovators would more likely to file for patent protection as they improve or advances the technology. It is then expected that the number of patent applications or grants during this stage be reasonably high. There should be a gradual increase in the number of units sold or advertised during this stage.

> Proposition 1: If the patent applications for feature enhancement increases significantly in a short period, the technology has entered the growth (PLC) or Acceptance stage.

Stage III – Dominance

The third stage of technology adoption life cycle, Dominance, starts when the supply catches up with the demand for items created by the technology. The main characteristic of the Dominance stage is that the rate of production on items using the technology will not decline in this stage, and it should achieve the highest level of consumption. The rate of the production may continue to grow until market saturation. How long a technology stays in the Dominance stage would depend on the technology's relative cost advantage when compared to newer technologies that challenge its position. The total supplied volume should be in sync with the demand for the items. It may be modified by a variety of factors such as the number of newer technologies that attempt to challenge its dominance, availability of raw material, changing preferences of the end users, or regulations. Hence, the total volume should, at the minimum, remain at the same level or increase with the demand for the item. Once a technology becomes the dominant technology, participating companies may choose from a wide variety of strategies to participate in the industry, such as differentiation, price leadership, or niche.

While it is possible that the technology may fall out of the Dominance stage and subsequently return to the Dominance stage, as explained earlier in the description of the Acceptance stage, the longer a technology remains in the dominance position, the less likely a regression will occur. The longer a technology remains in the dominance position, the more opportunity for a more efficient process to emerge and improve its cost advantage. The total cost would, given enough time, be close to the theoretical minimum for the technology. For a technology to lose the cost advantage when it is close to the minimum cost, the newer technology must have a cost advantage that the technology cannot overcome. Another possible reason that the consumer would abandon the technology is that the technology has some serious long-term flaws which a newer technology address.

Since sales are high, when compared to the other stages, the number of products sold and the number of different models sold during this stage would be high when compared with other stages. The number of patent applications during this stage would expected to be high during this stage. However, it may be possible to distinguish Dominance stage from the Acceptance stage via the type of patent applications in each period. This paper would propose that during the Dominance stage, the portion of patents relating to increase efficiency, or patents relating to the process, increase over time. Patents relating to changing the characteristic of the technology is expected to diminish over time.

Proposition 2: If patent applications relating to process improvement is more than the patent applications for feature enhancements or changes in characteristic, the technology is in maturity (PLC) or the Dominance stage.

Stage IV – Abandonment

The fourth stage of technology adoption life cycle, Abandonment, contains two sub-phases: Second Transition, and Post-Paradigm Shift. The main characteristic of this stage is a steady decline in the number of items created using the technology. The expected cause for a technology to enter this stage is because a newer technology has posed a successful challenge by having some cost advantage that the technology cannot overcome. Again, while it is possible that this transition is only a temporary one, the longer the technology stay in the Dominance stage, the less likely the technology will return to the Dominance stage. By being around for a long period of time, the improvement in the cost of servicing a need with this technology should have approached its limit. The marginal cost saving would have approached zero in improvement. If it is possible for a different technology to service the same need at a lower cost, it would suggest that the cost advantage from the technology is lost forever.

The Second Transition begins when there is a decline in the demand from items created by the technology. It is unlikely that there is a significant change in the industry's structure in this sub-phase; however, companies may be preparing to exit the industry because they may be experiencing losses. It may be possible to predict how companies using this technology will react in the second transition sub-phase.

However, as the decline in demand continues, the industry would experience another paradigm shift where items created by the newer technology would become the majority of the items produced in this industry. Once the post-paradigm shift begins, the items created by the technology should decline rapidly. Most companies utilizing the technology are expected to stop using this technology eventually; how quickly the companies stop using this technology would depend on the exit barrier. What is more interesting is how to predict which company will remain until the end of this sub-phase.

This paper speculates that as sales declines, the company would have shifted their resources away from researching the technology to improving the efficiency of its production process. Even filing for patent protection would have taken away valuable resources from the firm as they fight for their survival. Therefore, when the sales are in decline, there would be limited or negligible number of patent applications or grants.

> Proposition 3: There will be a period, after the mature (PLC) or Dominance stage, where there no patent applications for a technology.

Stage V – Specialization

The fifth and final stage, Specialization, can only happen if there exists some market segment where the technology still enjoys some limited advantage over the newer technology. The main characteristic of this stage is a predictable and stable demand pattern for items created by the technology, but the total volume would be much lower than during the dominance stage, perhaps less than 10% but further research would be needed to confirm.

The chance that the Specialization stage will be skipped would be high if the technology never enters the Dominance stage of the technology life cycle. For example, the format war between Blu Ray and HD DVD was won by the Blu Ray format. Since the HD DVD format never had the opportunity to enter the Dominance stage in the home video industry, the demand for the HD DVD product disappear after Blu Ray won the format war. On the other hand, while the Betamax format did not have the opportunity to enter the dominant stage because it lost the format war with the VHS system, there is still a small demand for this technology in the video industry even as users have started to access videos over the Internet.

It is expected that if a technology had an extended period of dominance, the chance that the technology would disappear from an industry would be lowered. Take the examples of the candle and the horse-drawn carriage. Both were replaced, one by the electric light bulb and the other by the automobile. Yet, both products still maintained a relatively predictable demand pattern in the 21^{st} century, as candles can be used to set mood or to provide desirable scents; and horse-drawn carriages are often a draw around city parks and are used by the

Amish. Hence, demand for candles and horse-drawn carriages, while low, still exist.

As sales volume stabilize, remaining companies that still uses the technology may return to enhancing this technology and the need to request for patent protection may return. If the number of patent applications or grants rises above the Abandonment stage, this would be a strong evidence that Specialization stage exist. The prerequisite is that sales, while low, remains stable.

Proposition 4: The length of time for a period in decline (PLC) or Abandonment and Specialization stages would be equal or greater than the combined period length of the growth and maturity (PLC) or the Acceptance and Dominance stages.

Proposition 5: There will be a period where an increase in patent applications for a technology.

Implications of Proposed Model

Future Research Investigation

To confirm or validate the proposed technology adoption life cycle model, future research can start with unit sales to plot technology adoption. For example, studies may plot the unit sales or dollar sales of smart phone and estimate the current stage followed by studies on patent research for confirmation. The comparison may need to supplement with unit sales or dollar sales of cell phones and land line phones. Other potential studies may include an examination of navigation technology with maps, then GPS devices, then GPS applications on smart phones; sales of LED light bulbs with florescent light bulbs and incandescent light bulbs; sales of dox-matrix printer, laser printer, and ink-jet printers; sales of floppy disks, CD, DVD, and USB flash drives.

For academic scholars interested in validating or improving the model, there are many potential research studies. Since the proposed demand pattern is derived from two theoretical perspectives with some anecdotal observations, one can test the various assumptions and inferences that are derived from the model. The main assumption used in building this model is that a paradigm shift will only occur when there is a cost advantage for the newer technology. However, can there be other underlining causes of a paradigm shift? Here, several in-depth case studies may be necessary to shed light on the various causes of a paradigm shift, and whether there are variables unrelated to cost at work in facilitating the paradigm shift. The trigger point offered here is when half of the demand is transferred to the newer technology, but one may check at what percentage would it become imminent that a paradigm shift will occur. It is posited here as 50%, but it may be at some other percentages.

Even if change in cost advantage is the reason for a paradigm shift, which of the three types of cost advantage is the most important cost for business executives to monitor? While it may be easy to argue that intrinsic discount cost advantage must exist for the technology to have even the slightest chance to enter the acceptance stage, when should companies start to investigate or invest in the newer technology?

Another interesting area of investigation would be to explore when companies that works with the dominant technology should anticipate the market to experience a second paradigm shift. How the length of a company's planning horizon affects its behavior or survival during the transition phase? What is the survival rate of leaders and followers of the industry during this transition phase? Should companies stop investing in a dominant technology as soon as a newer technology emerges with some intrinsic discount cost advantage over the dominant technology, or should they wait until the cost or usage cost advantage of the emergent technology becomes inevitable? Should these companies abandon and prepare to exit the business, or are there some other options?

Potential use for executives

As an example of how this model would impact on decision makers, one can focus on the automobile industry. Right now, there are three technologies that are haunting the auto-industry executives: internal combustion engine, hybrid technology, and the all-electric engine. While the internal combustion engine is the dominant technology, in the next ten years, there may be a change in the dominant technology. Which technology the auto-manufacturer executive should focus on is a multi-billion dollars question. A better understanding on the life cycle of technology adoption can assist these executives.

A better understanding of technology adoption's benefit would not be limited to just the existing industries. Artificial intelligence (A.I.) and robotics technology are advancing quickly and may be creating many more industries that can impact on jobs in the future, but knowledge of the replaced technology should not be forgotten. For example, if a stable supply of computer or electrical power is not available, the tools created by A.I. or the advances in robotics will no longer be used. A better understanding of technology adoption can help not just business executives, it may help the average employees as well by preparing them for the type of knowledge that they need to retain for the future.

Concluding Remarks

While this model is based on a small number of anecdote observation, the proposed technology adoption life cycle matches the real-world experience. Future work on this model is expected to be first tested by case analysis for specific technologies and mathematical model with simulations. Once there is a good collection of knowledge, the model should be validated by more extensive testing with empirical data analysis. If the model is validated, then we may find ourselves in a more effective and efficient world. If it can be demonstrated that a mature and existing technology can still be an efficient or effective way to satisfy some needs, then the resource saved can be used for more important or critical task in the economy. Understanding the scenario of when to use a mature or existing technology can help making investment decision as well.

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