Walden University

College of Management and Technology

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Wilson Zehr

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Walden University
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Abstract

Innovation and Market Leadership in a Technology Industry

by

Wilson Zehr

MBA, Portland State University, 1990

BS, Portland State University, 1986

Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

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Abstract

According to the Abernathy-Utterback (A-U) model, firms focus on technological product innovation early in the product lifecycle and then shift to process innovation as markets mature. However, there is no consensus on the forms that non-technological innovation can take. In addition, the A-U model, which guides innovators, does not include forms of non-technological innovation that are generally accepted by experts. In this study, a hybrid e-Delphi technique with an AHP decision model was used to evaluate the forms of innovation used to establish market leadership over the historical lifecycle of the personal computer industry in the United States. In Phase 1, an e-Delphi panel of 30 technology experts, each with more than 20 years industry experience, confirmed that product, process, marketing, and organizational innovation are the correct forms to consider. In Phase 2, the expert panel agreed, based on an analysis of 45 years of market leadership data, that market share leaders used product innovation early in the lifecycle, and then process innovation as the market evolved. The expert panel also determined that marketing and organizational innovation were the most important forms of innovation when the market was mature. This research provides new insights that have the potential to aid innovators in choosing the right form of innovation depending on lifecycle stage. The results could also be used as a baseline to extend the A-U model to other forms of non-technological innovation. This is an essential piece of knowledge that can guide the next generation of innovators, create significant additional wealth, drive job creation and employment, reduce crime, and increase charitable giving.

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Dedication

This research work is dedicated to my son Mason who offered love and support even when the journey sometimes felt long and dark. It is also dedicated to Maggie, our friend, and the world's sweetest Pitbull, for being understanding when walks were less frequent and research work delayed dinner (often until late).

Thank you to my Dad who helped me appreciate the value of school, gave me the opportunity to pursue my education, and encouraged me to pursue my doctoral studies to their completion. Thank you to my Stepmother who welcomed and supported me when I decided to return to school and still continues to love and support my Dad. Thank you to my Mom who originally introduced me to literature, encouraged me to strike out on my own, and has been a frequent source of advice, debate, and inquiry. Thank you to my grandparents for providing the foundation that our family was built on.

This work is also dedicated to all those who have offered their love and support over the course of life's journey. Some are still with us, many are not. You may not know who you are, or even understand the role that you played. Yet, you have still earned a special place in my heart. Thank you for all that you have done.

Acknowledgments

In 1990, when applying for the MBA program at Stanford University, Dr. Virgil Miller, Dean of the College of Business at Portland State University (PSU), convinced me to enroll in the joint MBA/Systems Science Ph.D. program at PSU instead. It was a great opportunity to pursue my education (practical and theoretical), minimize the debt associated with my studies, and continue to pursue my professional career in technology and entrepreneurship. That was really the beginning of this journey.

Systems Science is a multi-disciplinary degree and the focus of my studies was systems theory, finance, and quantitative economics. Dr. John Oh was my finance and econometrics advisor and Dr. Harold Linstone ran the Systems Science department at PSU. I completed the coursework for the degree, but left the program to further pursue my professional career before my dissertation was complete.

In 2007, Dr. Steve Braun, offered me the opportunity to return to academia and share my practical experience in business and entrepreneurship at Concordia University (Portland, OR). Concordia wanted me to return to PSU and complete my degree. Admiral Dave Albrecht (retired) and Dr. Ron Miolla were both close colleagues, and mentors, at Concordia, who supported my work and encouraged me to complete my degree.

Given the amount of time that had passed since my prior degree program at PSU, the Graduate Studies Office directed me to start over. In order to avoid re-taking the same academic material over again, and to leverage my professional experience in technology and entrepreneurship, I enrolled in the Engineering and Technology Management (ETM) Program at PSU. Dr. Dundar Kocaglu (Dr. K) was my Committee Chair, faculty advisor,

and a constant inspiration. Dr. Tugrul Daim, who also pursued a professional career in technology, was an important mentor, supporter, and academic role model.

Eastern Oregon University (EOU), where I currently teach in the College of Business, required completion of my terminal degree for tenure. When Dr. Kocaglu retired in 2016, PSU was no longer willing (able) to support my Ph.D. research work, and I made the transition to Walden University (Minneapolis, MN). Dr. Craig Barton has been my primary mentor and a guiding force since my arrival at the university. Dr. Holly Rick, Dr. Raghu Korrapati, Dr. David Gould, Dr. Keri Heitner, and Dr. Jeffrey Prinster have all played important roles in this final leg of the journey.

My university colleagues (and friends) Dr. Gary Keller and Dr. Peter Maille provided much needed encouragement, support, and advice. Holly Chason provided critical assistance with research technique and tools. Dr. Robert Butler and Dr. John Thurber both provided valuable insights on portions of my research.

There are undoubtedly others who played important roles in this journey. I apologize in advance for those I've missed. You should know your role was both important and sincerely appreciated.

When using Google Scholar (often) in this research process, I'm always struck by the phrase "Stand on the shoulders of giants" featured on the home page. You are all the giants and I could not have reached this point without your help, support, guidance, and encouragement. Thank you for keeping the faith and for allowing me stand on your shoulders. I am forever in your debt.

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Chapter 1: Introduction to the Study

Innovation has been shown to fuel economic growth, create jobs, and provide significant improvement in people's lives (Ahlstrom, 2010; Baumol, 2002; Baumol & Strom, 2007; Christensen & Raynor, 2003). Innovation has also been responsible for 80% of U.S. economic growth since World War II (Atkinson, 2011). In spite of the documented linkage between innovation, economic development, and improved quality of life; there are many different perspectives on the forms that innovation can take (Foss & Saebi, 2017; Organization for Economic Cooperation and Development [OECD], 2018; Zott, Amit, & Massa, 2011), there is no unified theory of innovation (Fagerberg, 2018; Gopalakrishnan & Damanpour, 1997), and the tools that could help innovators understand the stage of the lifecycle where different forms of innovation are most effective, are incomplete (Utterback, 1994). The goal of this study was to highlight the benefits of innovation, understand where gaps exist in theory and practice, explore alternative approaches and perspectives, and suggest a path forward that could help future innovators harness the power of innovation for economic growth and social good.

This chapter begins with a background for the study and highlights the importance of innovation in the process of creating economic value. The specific purpose of this study and the problem being explored are outlined, along with the research question that guides this investigation. The nature and scope of the study are covered, along with the underlying definitions, assumptions, and limitations. Finally, this chapter contains an outline of the significance of this study to theory, practice, and social change.

Background of the Study

Lindgart, Reeves, Stalk, and Deimler (2009), in an annual study of top business innovators, confirmed that companies identified as business model innovators, produced returns four times greater than those identified as product or process innovators. They also found that those returns were more sustainable lasting 10 years or more. To illustrate, the introduction of iTunes in 2003 represented a significant organizational innovation for Apple (Snihur & Wiklund, 2018). This innovation increased iPod product revenue by $345 million (140% increase) in the first year and continued to grow to $8.3 billion (45% of total revenue) by 2007 (Yoffie & Slind, 2008). It is still more common for business innovators to consider innovation only in terms of technology applied to product/process innovation (Fagerberg, 2018; Medrano & Olarte-Pascual, 2016).

The OECD, the foremost international authority on measuring innovation (OECD, 2019), officially recognized only technological product and process innovation from 1997 to 2005 (OECD, 1997). Utterback (1994), building on Utterback and Abernathy (1975), showed that firms focus on product innovation early in the lifecycle, and then shift to process innovation as markets mature. This body of research, which guides innovators and researchers, is generally referred to as the A-U model (Akiike, 2013). The absence of non-technological forms of innovation, in foundational tools such as the A-U model, exposes a gap in the literature.

Problem Statement

The general problem is that there is no consensus on the forms that non-technological innovation can take. In 2005, in the third edition of the Oslo manual, the

OECD officially recognized product, process, marketing, and organizational innovation (OECD, 2005, 2009). The OECD also de-emphasized the role of technology to accommodate products offered by services companies. In the latest version of the Oslo manual, the fourth edition; the definition has again changed to focus on product or process innovation (OECD, 2018). In this definition, a product can take the form of a product, service, or a combination of the two. Process innovation has been expanded to include (a) production processes, which matches the definition of process innovation outlined in the third edition of the Oslo manual and used in conjunction with the A-U model, (b) distribution and logistics, (c) marketing and sales, (d) information and communication systems, (e) administration and management, or (f) product and business process development. Others in research and practice have presented many other options which include: business model innovation (Foss & Saebi, 2017; Zott et al., 2011), marketing innovation (Gupta & Malhotra, 2013; Michel, 2014; Zhou, Yim, & Tse, 2005), and innovation frameworks (Keeley, 2013; Moore, 2005).

The specific problem is that the A-U model, which guides innovators and researchers (Akiike, 2013; Teece, 1986), does not include forms of non-technological innovation that are generally accepted by experts (OECD, 2018). These new forms of innovation have been shown to produce returns that are four times larger, and far more sustainable, than traditional product/process innovation (Lindgart et al., 2009).

Purpose of the Study

The purpose of this qualitative e-Delphi research study was to build consensus with an expert panel of innovators and researchers on the form(s) of innovation used to

establish market leadership over the historical lifecycle of a technology industry. The results of this study may be added to the A-U model (see Utterback & Abernathy, 1975) to create a baseline for non-technological innovation within that framework and guide the work of future innovators.

Research Questions

What is the consensus of an expert panel of innovators and researchers on the form(s) of innovation that were used by competitors to establish market leadership over the historical lifecycle of a technology industry?

Conceptual Framework

Schumpeter (1934) first recognized the central role innovation plays in creating new markets and destroying old ones. The process was described as creative destruction, an activity that was thought to be central to economic growth. Schumpeter (1934) saw this as the role of the *Entrepreneur* in their quest for competitive advantage. Research now shows that innovation has been responsible for 80% of the U.S. economic growth since World War II (Atkinson, 2011) and continues to be a driving force behind economic expansion and wealth creation (Bristow & Healy, 2018; OECD, 1997). The nature of Schumpeter's work is explored further in Chapter 2.

Rogers (1962) first outlined the concept of diffusion of innovations, a theory that explains how new innovations are spread and adopted. Based on this theory, innovations are brought to market, and used first by innovators, then early adopters, late adopters, late majority, and finally laggards. There is no guarantee that the adoption of an innovation will reach these groups; innovations can die out at any stage of innovation. The curve that

describes the overall adoption of new innovations across all stages is known as the S curve of innovation (Rogers, 2003). This concept is outlined in more detail in Chapter 2.

The work of Rogers (1962) was based primarily on technological advances applied to product innovation. In fact, Rogers quite frequently used the words technology and innovation as synonyms (Sahin, 2006). This is a limited view of innovation that is shared with many others as well (Atkinson, 2013). Utterback and Abernathy (1975), expanded on that theory to show that when a new industry begins to emerge around a class of innovative change, there are initially many market entries with competing approaches. Over time, markets tend to consolidate around a dominant design. Once a market begins to mature, and a dominant design is established, the focus for innovation shifts to process innovation to improve efficiency and establish a competitive cost advantage. The A-U model, first developed by Utterback and Abernathy (1975), and refined by others, is explored in more detail in Chapter 2.

Since the seminal work of Utterback and Abernathy (1975), there have been a several researchers and practitioners who have proposed other forms of innovation besides product and process innovation. The OECD, an international research organization that represents over 100 member and non-member countries, now recognizes product and process innovation, with process innovation spanning the functions of production, distribution, marketing, information systems, management, or business process (OECD, 2018). Others in research and practice have presented other options which include: business model innovation (Foss & Saebi, 2017; Zott et al., 2011), marketing innovation (Gupta & Malhotra, 2013; Michel, 2014; Zehr, 2016; Zhou

et al., 2005), and other forms of innovation frameworks (Keeley, 2013; Moore, 2005). These other concepts of innovation, some that have been shown to produce far greater returns than strict product or process innovation (Lindgart et al., 2009), are also investigated further in Chapter 2. The results of this research study could be used to extend the A-U model to other non-technological forms of innovation besides product or process innovation to guide the work of future innovators.

Nature of the Study

This qualitative e-Delphi study will use an analytical hierarchical process (AHP) decision model, to help build consensus among a panel of expert innovators and researchers. Experts who participated in this study were asked to identify the sources of innovation used by market share leaders in a technology industry. The Delphi method is well established as a qualitative tool that can help build consensus among panels of experts (Linstone & Turoff, 2011; Skinner, Nelson, Chin, & Land, 2015; Strasser, 2017). On the other hand, AHP can be used to form a mathematical consensus when decisions are based both on fact and on judgement (Saaty, 2008). The combination of both techniques allowed removal of the subjectivity that can be associated with the Delphi method (Hsu & Sandford, 2007) and assured that mathematical consensus was achieved.

Saaty (1980) originally developed AHP in the 1970s as a way of addressing weapons tradeoffs, resource and asset allocation, and decision making, when working with the State Department's Arms Control and Disarmament Agency, and as a Professor at the Wharton School of Business (Alexander, 2012). Saaty (1980, 1995, 2008), and Golden, Wasil, and Harker (1989), demonstrate that when choices are ranked based both

on fact and individual judgment, the AHP decision model is an effective tool. This methodology is based on expert opinion to establish priorities for specific decision criteria, then the results of pairwise comparisons are used to establish a ranking for the same criteria associated with each decision alternative, and then these weights are used to identify the best choice. This AHP research technique has been applied in a wide number of applications and industries (Lee, Kwak, & Han, 2007; Phan & Daim, 2011; Zehr, Alawini, Alharbi, & Borgan, 2014).

The Delphi method originated in the 1950s at the RAND corporation where it was used to forecast the influence of technology on conflict and warfare for the U.S. Air Force (Dalkey & Helmer, 1963). The underlying concept was to leverage the intuition and judgement of experts, especially in cases where formal mathematical models or well-accepted problem solving techniques did not exist (Linstone & Turoff, 1975). The key characteristics of Delphi include: (a) *anonymity* (respondents should not feel pressure from other participants), (b) *iteration* (participants may change or refine their opinion based on the responses of others), (c) *controlled feedback* (presenting feedback in an organized and objective fashion without allowing any one participate to dominate the discussion), and (d) *statistical group response* (the dispersion of the final responses can provide an indication of the level of consensus achieved; Landeta, 2006).

Ludwig (1997) noted, the majority of Delphi studies are conducted with a panel that consists of 15 – 20 expert participants. The panel in this study was composed of 20 experts in the specific technology industry under consideration. Purposeful selection based on a LinkedIn invitation and profile review was used to recruit participants who are

experts on the subject matter. LinkedIn is the worlds largest online social media network with over 660 million professional users in more than 200 countries (LinkedIn, 2020a). Over 50% of Americans with a college degree use LinkedIn (Tran, 2020) and the network reach includes more than 10 million C-level executives (LinkedIn, 2020b) and has professionals from every Fortune 500 company (Fortune, 2020). The network has been shown to be effective for performing research with professionals, especially in cases where the intent is to span a variety of companies and industries (Huang, Tunkelang, & Karahalios, 2014; Unkelos-Shpigel, N., Sherman, S., & Hadar, 2015). In Delphi research we are looking for experts on a specific topic, rather than a statistical sample of the entire population of experts, so sample bias should not be an obstacle (Zhang & Vucetic, 2016).

A traditional Delphi process typically consists of three to five rounds; though the goal of the Delphi technique is to reach consensus among the participants, and any number of rounds may be used (Hsu & Sandford, 2007). In the first-round participants typically respond to an exploratory questionnaire. In the second-round, responses are consolidated by investigators and participants are asked for their position on the consolidated statements. A similar process of consolidation and revision continues for the third and as many subsequent rounds as required. The right number of rounds should ultimately be determined by the complexity of the subject matter and the degree of consensus required by investigators (Linstone & Turoff, 1975).

The advantage of the Delphi approach is that it allows investigators to tap into the specialized knowledge of experts to make informed decisions or forecasts (Hsu & Sandford, 2007). The limitations of the traditional approach are that (a) consolidating and

revising questions is subjective and can be subject to group influence, (b) the coordination of a group of experts can prove daunting in terms of the time required, and (c) there is no guarantee that a (useful) consensus will be reached no matter how many rounds are used. Donohoe, Stellefson, and Tennant (2012) an e-Delphi process, using electronic communication, to streamline communication and make the process transparent for the expert participants. This research study used e-Delphi techniques to streamline the communication process (no more than three rounds) and AHP techniques to reduce the level of subjectivity and assure that consensus was achieved.

Definitions

Entrepreneur: The concept of an entrepreneur was used in traditional economics literature by Adam Smith, Richard Cantillon, who first used the term "entrepreneur", and Jean Baptiste Say, who was recognized as the scholar who introduced the character of an entrepreneur to economic theory (Śledzik, 2013). Schumpeter (1942) presented the following definition: "

> "The function of entrepreneurs is to reform or revolutionize the pattern of production by exploiting an invention or, more generally, an untried technological possibility for producing a new commodity or producing an old one in a new way, by opening up a new source of supply of materials or a new outlet for products, by reorganizing an industry and so on." (p. 132)

The field has continued to evolve, and more contemporary definitions are focused on taking risk and creating an enterprise. A more contemporary definition can be found in Barringer and Ireland (2016): "Entrepreneurs assemble and integrate all the resources

needed (money, people, business model, and strategy) required to transform an invention or an idea into a viable business" (p. 6). The concept of social entrepreneurship, building ventures to benefit social causes, has been around since the 1950s; however, this field of study has gathered more attention and grown in significance over the last decade (Saebi, Foss, & Linder, 2019).

Innovation: The OECD (2018) defines business innovation as a new or improved product or business process (or combination thereof) that differs significantly from the firm's previous products or business processes and that has been introduced on the market or brought into use by the firm. The third edition of the Oslo manual (OECD, 2005) defined an innovation as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization, or external relations. These innovations can be new to the industry, new to the industry, or new to the world (OECD, 2018). There are many different definitions of innovation, and many approaches for defining innovation, and these are explored in more detail in Chapter 2. This research study used the definition of innovation from the third edition of the Oslo manual (OECD, 2005).

Organization for Economic Cooperation and Development (OECD): The OECD was formally created in 1961 as an outgrowth of the Organisation for European Economic Cooperation, which was set up in 1948 to implement the Marshall plan; a plan focused on rebuilding Europe after World War II (Coggan, 2017). Today the OECD is an organization representing 36 democracies with market-based economies, and more than 70 non-member countries, that performs research and advocates for policies that

encourage innovation and sustainable economic development (OECD, 2019). OECD member countries are responsible for 63% of world GDP, 75% of world trade, and 95% of official development assistance for the world (U.S. Mission to the OECD, n.d.).

Personal computer (PC): A personal computer is a low cost, general-purpose computer, equipped with a microprocessor, that is designed to be used by a single user. A PC can be a micro-computer, desktop computer, a laptop computer, a tablet computer or a handheld computer (Janssen & Janssen, 2011). Personal computers can run a number of operating systems including Microsoft Windows, Mac OS, Chrome, Linux, or others (the form and function of the computer rather than the vendor or the operating system define a PC) according to Christensson (2007). An Apple Mac is a personal computer (Bott, 2014).

Product: The OECD definition for innovation relies on the definition of product provided by the System of National Accounts (SNA). The SNA defines products as goods and services that are the result of production. These production outputs can be exchanged and used for various purposes; as inputs in the production of other goods and services, as final consumption, or for investment (United Nations, 2009). Kotler and Armstrong (2017) define a product as anything that can be offered in a market for attention, acquisition, use, or consumption, that might satisfy a need or want. The want or need can be satisfied with a physical product, a service, information, or an experience.

The product can occur on at least five basic levels, the core customer benefit, generic product, expected product, augmented product, and potential product (Kotler & Armstrong, 2017). The core benefit is the problem solved by the physical product, service, information, or experience. The generic product consists of the minimal design,

features, packaging, brand, and other attributes required to deliver the core benefit. The expected product expands this concept to include the characteristics that customers would expect to find in that class of product. The augmented product includes the core benefit, the generic product, the expected product, and any other elements designed to distinguish (differentiate) from competitors. The potential product recognizes what the product could someday become. Davidow (1986) makes the point that there is a difference between a device and a product. This is similar to what Moore (1991) referred to as the whole product when applied to a specific target audience. This is the same distinction that Kotler and Armstrong (2017) made between the generic product and the augmented product. Zehr (2016) extended this further with the concept of a market offering, which includes the core benefit, the augmented product, and all the elements of the marketing mix.

Resource-based view (RBV): The RBV is managerial framework that indicates organizational performance is determined primarily by internal capabilities and resources that can be grouped into three all-encompassing categories: physical resources, human resources, and organizational resources. Capabilities are used by organizations to transform resources into market offerings. Core competencies are capabilities that are valuable, rare, difficult to imitate, and non-substitutable (Hitt, Ireland, & Hoskisson, 2016). Sustainable competitive advantage comes from building strategies around core competencies (David & David, 2017; Rothaermel, 2008).

Assumptions

Competitors in a market have access to the information, resources, and basic competencies they need to compete in that market. Without innovation (in some form) the best they could hope for is market parity (Baumol, 2002). The RBV states that strategic advantage comes from building strategies around core competencies. These competencies stem from innovations which are unique to the firm in the short-term. In the long-term the value of any specific competency can wane as competitors find ways to replicate these capabilities, develop others that are even more compelling, or markets evolve in a way that makes them less important (David & David, 2017).

Rogers (1962, 1976, 2003) showed that in markets and social eco-systems, when the adopter has a choice, innovations are adopted following a normal distribution. New innovations are used first by innovators (2.5%), then early adopters (13.5%), early majority (34%), late majority (34%), and finally laggards (16%). This growth is associated with a rapid growth rate in market expansion that eventually slows and enters decline. This study will include market growth rates (+/-) to approximate the stage in the adoption lifecyle as proposed by Rogers. This study is based on Rogers' (2003) diffusion of innovation model to establish the stage in the lifecycle for market leadership and innovation.

Companies in the PC industry all have access to similar technology. It is common for vendors to have multiple PC models that use different generations of technology to meet specific price points and the computing needs for different market segments. The technology associated with microprocessors, memory, persistent storage, and other

functions, are sophisticated components, with their own lifecycle, and it would not make economic sense to produce these components in small volumes for the computers offered by a single vendor. Most of these components are available to all participants as soon as they are available in the market (Carlson, 2006; Steffens, 1994).

In this study, I assumed that the political, economic, social, technological, ecological, and legal (PESTEL) operating environment and the stage in the business cycle affects all players equally in the U.S. PC market. In practice, some innovations and strategies will be more appealing in specific operating environments. For example, consumers and businesses tend to be more price sensitive during a downturn in the economic cycle. This would tend to favor those competitors pursuing a low-cost strategy during that timeframe at the expense of those that did not. PESTEL factors were considered when interpreting the results of this research project.

I assumed that the market share numbers provided by International Data Corporation (IDC), Gartner Group, and Ars Technica (Reimer, 2005) are accurate and complete. I also assumed that a sufficiently large panel of experts existed and that they would be available and willing to participate in this study through all phases of the research process.

Scope and Delimitations

The focus of the study was the PC industry in the United States covering the period from 1975 to 2019. The PC industry, which started in the United States in 1975 (Reimer, 2005), experienced double digit growth rates in the 1970s through the 1990s (Carlson, 2006). The industry peaked in 2011, has shown declining rates of growth since

then, and declines are projected to continue (Richter, 2018). This is an example of a mature industry where data exists to explore the entire historical lifecycle (womb to (potential) tomb). This pattern of evolution presents a unique opportunity to explore sources of innovation chosen by market leaders and judge the effectiveness of each approach over time.

The research of Utterback and Abernathy (1975) and Utterback (1994) showed that the focus of innovation activities in firms is on product innovation early in the lifecycle, and then this shifts to process innovation as markets mature. The original Utterback and Abernathy (1975) study was based on a dataset from a Myers and Marquis (1969) study of 567 commercially successful innovations (from five industries and 120 firms). This current study was based on market share leaders over the entire historical lifecycle for a specific technology industry. This is a much more industry-specific data set then that used by Utterback and Abernathy (1975). The analysis may need to expand to a greater range of industries to produce results that are generally applicable like the A-U model.

One unique aspect of the PC industry is that, even though it is a technology-driven industry, most PC vendors do not invest in creating proprietary new technology for the core components of the devices such as processor, storage, and memory. These components are far too specialized and would be cost prohibitive to produce without significant industry volume. The creation of core technology is the work of specialized suppliers that make their designs available to any number of vendors (Carlson, 2006; Copeland & Shapiro, 2010; Einstein & Franklin, 1986; Langlois, 1992). It is not

uncommon for PC vendors to offer different models, based on different technologies or stages of evolution, at different price points, at the same time, to meet the needs of different market segments (Bayus, 1998; Bayus & Agarwal, 2007; Steffens, 1994). This also implies that any competitive advantage related to core technology can be overcome by selecting different components or suppliers.

In this type of operating environment, even though the PC industry is one that is technology-driven, technological innovation is not a source of "sustainable" competitive advantage (David & David, 2017). The nature of competition and the operating environment can change based on the industry and the environmental forces at work at any moment in time (David & David, 2017; Hitt et al., 2016). That could limit the application of research results to industries that have similar constraints and market dynamics (Pakes & Ericson, 1998).

Limitations

This research study was based on a e-Delphi research method using an AHP decision model. The literature is rich with examples of the Delphi method in practice (Donohoe & Needham, 2009; Gallego & Bueno, 2014; Hallowell & Gambatese, 2009; Strasser, 2017). In a similar fashion, there are many examples of the AHP method in research and practice (Saaty, 2008; Saaty & Vargas, 2012). Both methodologies are typically used for making complex decisions in situations that involve both fact and expert insights. With AHP, the technique is often used with multi-stage, hierarchical decisions. In this case, the decision regarding the form of innovation has already been made by the (operators) innovators in the technology industry being investigated. The

original competitive decision would have been based on internal and external environmental factors, besides lifecycle stage, that were not visible to the panel in this study. In this study, I only considered the innovation choice and the stage of the lifecycle, and did not consider other qualitative elements.

When using expert opinion, there is always the possibility of bias on the part of individual experts. The Delphi process relies on this richness of diversity in the expert panel to make sure that the outcome embodies multiple viewpoints (Dalkey, 1967; Linstone & Turoff, 1975; Linstone & Turoff, 2002). One other risk of the Delphi technique is that too many rounds can lead to panel fatigue and dwindling panel participation if convergence requires many rounds. Research by Brockhoff showed only a minimal increase in convergence beyond three rounds (Linstone & Turoff, 2002). The version of Delphi used in this research project was based on an AHP decision model to assure rapid convergence.

Significance of the Study

Significance to Theory and Practice

The findings of this qualitative Delphi study may be used to build consensus on the form(s) of innovation used by leaders in a technology industry to establish market share leadership at each stage of the historical product lifecycle. The findings may also provide insight into the effectiveness of specific forms of non-technological innovation at different stages in the lifecycle for a technology industry.

Utterback (1994) demonstrated that innovators concentrate on technology applied to product innovation early in the product life-cycle. Once a dominant product design has

been established, the focus shifts to process innovation. The A-U model, first developed by Utterback and Abernathy (1975), and refined by others over time, is still a cornerstone of innovation theory and practice today (Akiike, 2013).

The latest version of the Oslo manual, published by the OECD, now recognizes two broad categories of innovation, product innovation and process innovation, with the latter broken into six sub-categories: (a) production processes, (b) distribution and logistics, (c) marketing and sales, (d) information and communication systems, (e) administration and management, and (f) product and business process development. This definition includes at least four new forms of non-technological innovation, categories 3 - 6, that were not included in the original A-U model. In addition, there is still widespread disagreement in both academic and professional literature concerning the composition of new categories of non-technological innovation such as marketing and organizational innovation (Foss & Saebi, 2017; Osterwalder, Pigneur, & Tucci, 2005).

The findings of this research study may be used to identify market share leaders in a technology industry and build consensus on the forms of innovation used to establish market leadership. The forms of innovation considered include forms of technological and non-technological innovation recognized by the OECD. This may provide guidance to innovators seeking to pursue innovation and market leadership at different stages in the lifecycle.

Significance to Social Change

Innovation has been shown to fuel economic growth, create jobs, and provide significant improvement in people's lives (Ahlstrom, 2010; Baumol & Strom, 2007; Christensen & Raynor, 2003). Innovation also has the potential to help the world's poorest people at the bottom of the pyramid improve the quality of their lives (Prahalad, 2004).

Innovation has been responsible for 80% of U.S. economic growth since World War II (Atkinson, 2011). Innovation can lead to significant new products that expand existing markets or create completely new ones (Christensen, 1997; Christensen & Raynor, 2003). The top five publicly traded U.S. firms in terms of market capitalization are Apple, Alphabet (Google), Microsoft, Amazon, and Facebook (Desjardins, 2016; Kiesnoski, 2017). In 2018 Apple became the first company in history to break $1 trillion in market capitalization (Salinas, 2018). In 2019, Microsoft crossed the $1 trillion market capitalization threshold to become the most valuable company in the world (Kilgore, 2019). These five companies also represent the most valuable global brands (Frangoul, 2017). Of these top companies, only two, Microsoft which was started in 1975, and Apple which was started in 1976, existed before 1994. Amazon was started in 1994, Alphabet (Google) was started in 1998, and Facebook was started in 2004. These companies were all propelled to the top by significant innovations that they created and brought to market.

The U.S. Bureau of Labor Statistics reports that over 48 million jobs, 46% of the U.S. labor force, were created by firms that started after March 1993 (Sadeghi, 2010).

Economic expansion creates jobs, reduces unemployment, and increases wages (Keynes, 1960). Research based on the Federal Bureau of Investigation (FBI) universal crime reports has shown that declining unemployment rates and increasing wages are associated with lower rates of property-related crime (Lin, 2008; Mustard, 2010; Raphael & Winter-Ebmer, 2001). Lower levels of unemployment can also improve physical health, mental health, and reduce the risk of stress related death (Bartley, 1994). An increase in income and output also leads to larger amounts of charitable giving (Daniels, 2015; Havens, O'Herlihy, & Schervish, 2006).

Innovation can also improve the efficiency of existing markets allowing us to increase output with fewer economic inputs. Shumbaugh, Nunn, and Portman (2017) noted that U.S. total factor productivity (TFP) growth was rapid in the decade just after WW II, slowed in the early 1970s, and then showed a brief increase beginning in the mid-1990s. Cardarelli and Lusinyan (2016) showed the results have been slow to negative since that time. These results demonstrate an alarming trend, given that productivity growth is pivotal to improving the standard of living over time (Solow, 1957). One of the key ingredients for productivity growth is innovation (Shumbaugh et al., 2017). Providing more effective tools for innovators, has the potential to further increase the standard of living here, and help even those at the bottom of the pyramid enjoy better lives (Prahalad, 2004).

Summary and Transition

In summary, innovation has been shown to fuel economic growth, create jobs, and provide significant improvement in people's lives (Ahlstrom, 2010; Baumol & Strom,

2007; Christensen & Raynor, 2003). Innovation has also been responsible for 80% of U.S. economic growth since World War II (Atkinson, 2011). In spite of the documented linkage between innovation, economic development, and improved quality of life, there are many different opinions on the forms that innovation can take (Foss & Saebi, 2017; OECD, 2018; Zott et al., 2011), there is no unified theory of innovation (Fagerberg, 2018; Gopalakrishnan & Damanpour, 1997), and the tools that could help innovators understand the stage of the lifecycle where different forms of innovation are most effective, are incomplete (Utterback, 1994).

The general problem is that there is no consensus on the form(s) that non-technological innovation can take (Foss & Saebi, 2017; Keeley, 2013; Moore, 2005; OECD, 2018; Zhou et al., 2005). The specific problem is that the A-U model, which guides innovators and researchers (Akiike, 2013; Teece, 1986), does not include forms of non-technological innovation that are generally accepted by experts (OECD, 2018). These new forms of innovation have been shown to produce returns that are four times larger, and far more sustainable, than traditional product/process innovation (Lindgart et al., 2009). Innovation can also have a significant impact on social change. Innovation is responsible for over 80% of us economic growth since World War II (Atkinson, 2011), the creation of significant wealth (Salinas, 2018), lower levels of property-related crime (Lin, 2008; Mustard, 2010), and higher levels of charitable giving (Daniels, 2015; Havens et al., 2006).

The purpose of this research project was to build consensus with an expert panel of innovators and researchers on the forms of innovation used to establish market

leadership over the historical lifecycle of a technology industry. The study was based on a e-Delphi research process (Dalkey & Helmer, 1963; Donohoe et al., 2012) with an AHP decision model (Saaty, 2008) to remove the subjectivity often associated with Delphi (Hsu & Sandford, 2007). The results may be added to the A-U model to create a baseline for non-technological innovation within that framework.

The focus of Chapter 1 was to provide the context for the research study outlined above. In Chapter 2, I provide a detailed review of the literature with respect to the conceptual frameworks used, the evolution of significant theories in innovation, and highlight important contemporary topics in innovation from a macro-economic perspective. The chapters that follow include the details of the research method, the research results, the implications of the study, and avenues for potential follow-up research.

Chapter 2: Literature Review

The general problem was that there is consensus on the form(s) that non-technological innovation can take. In the latest version of the Oslo manual, the fourth edition, the definition of innovation focuses on product or process innovation (OECD, 2018). A product can take the form of a product, service, or a combination of the two. Process innovation has now been expanded to include (a) production processes, (b) distribution and logistics, (c) marketing and sales, (d) information and communication systems, (e) administration and management, or (f) product and business process development. Others in research and practice have presented many other options which include: business model innovation (Foss & Saebi, 2017; Zott et al., 2011), marketing innovation (Gupta & Malhotra, 2013; Michel, 2014; Zhou et al., 2005;), and innovation frameworks (Keeley, 2013; Moore, 2005).

The specific problem was that the A-U model, which guides innovators and researchers (Akiike, 2013; Teece, 1986), does not include forms of non-technological innovation that are generally accepted by experts (OECD, 2018). These new forms of innovation have been shown to produce returns that are four times larger, and far more sustainable, than traditional product/process innovation (Lindgart et al., 2009).

The purpose of this qualitative e-Delphi research project was to build consensus with an expert panel of innovators and researchers on the forms of innovation used to establish market leadership over the historical lifecycle of a technology industry. The results may be added to the A-U model to create a baseline for non-technological innovation within that framework to provide guidance for future innovators.

The chapter begins with an outline of the literature search strategy for this study. The theoretical foundation and conceptual framework associated with the study are explored in more detail. Finally, a developmental literature review is provided. The process begins with an exploration of the historical evolution of innovation theory, highlighting the key studies and thought leaders, that helped guide that transformation. A number of popular topics in the contemporary study of innovation are then be further explored. The goal of the literature review is to illustrate where the United States has come from, in terms of innovation theory, and highlight other areas that are still developing.

Literature Search Strategy

Research on the topic of innovation started with a review of the recognized seminal works in academic and business publishing in the field. This list included Schumpeter (1934), Rogers (2003), Freeman (1974), Utterback and Abernathy (1975), Porter (1985, 1990), Van de Ven (1986), Anderson and Tushman (1990), Christensen (1997), Moore (2005), Drucker (1998, 2002), Von Hippel (2005), Osterwalder (2004), and others. This review was further expanded by using the references provided in these works as a guide and augmenting with two decades of work by OECD.

Using this research as a foundation, additional searches were performed of peer reviewed journal articles, magazines, books, Internet searches, dissertations, and eBooks. The search process involved the use of the following databases and search engines: EBSCO (Business Source Complete), GALE (Business Economics and Theory Collection), SAGE, Academia, JSTOR, Google Scholar, Emerald Management Journals,

Statista, Harvard Business Publishing, MIT Publishing, and others. The search results were generated by entering the following words and phrases: *innovation, history of innovation research, innovation economics, economics of innovation, diffusion of innovation, product innovation, process innovation, business model innovation, marketing innovation, organizational innovation, disruptive innovation, dominant platform, models of innovation, measuring innovation, personal computer (PC) industry, PC market share, PC competitors, PC market dynamics, mathematical model innovation, economic model innovation, quantitative innovation research, case study research, grounded theory research, Delphi method, analytical hierarchical process (AHP)*, and others.

Conceptual Framework

The spread of a product, process, or idea, innovation is referred to as diffusion in the marketing literature (Peres, Muller, & Mahajan, 2010). In the case of technological innovations, the process can be described as technology diffusion (Lotfi, Lotfi, & Halal, 2014). Kumar (2015) noted, the concept of diffusion was first introduced by Tarde (1903) and is now referred to as the law of adoption. Schumpeter (1934, 1939) further refined the idea by grouping technological change into a three-phase trilogy: invention, innovation, and diffusion. Kumar (2015) outlined two recurring themes in the literature generally adopted by researchers and scientists. Social scientists such as sociologists, geographers, social anthropologists, and development planners, tend to consider the micro-level socio economic factors, similar to the spread of a species or disease. On the

other hand, technology planners, market researchers, and marketing practitioners, tend to study the spread of innovation at the macro-level focusing on communication issues.

Rogers (1962, 1976, 2003) and Rogers and Shoemaker (1971), outline a model for diffusion of innovations which has become widely established in the marketing literature (Wright & Charlett, 1995). The book, *Diffusion of Innovations*, is now in its 5th edition, with the distribution of each edition reaching more than 30,000 (Goodreads, 2019). Rogers diffusion theory explains how innovations are adopted by a social system, the barriers that can exist, and outlines a typical pattern. The diffusion process consists of four key elements: (a) an innovation, (b) the social system impacted by the innovation, (c) communication channels within that social system, and (d) the time involved (Rogers, 2003). Rogers defined diffusion as the process by which an innovation is communicated through channels over time among members of social system (Rogers, 2003). This definition is also supported by Golder and Tellis (2004), Mahajan, Muller, and Wind (2000), Mahajan, Muller, and Bass (1990), Bass (1980), and others. Gatignon and Robertson (1985) provided a detailed analysis of these elements and research related to each. Chandrasekaran and Tellis (2007) provided the definition "the state of being spread out or transmitted especially by contact, trade, or conquest" (p. 39). Diffusion in Rogers model is a five stage evolutionary process consisting of awareness, interest, evaluation, trial, and adoption (Rogers, 2003). Diffusion within a social system can be affected by both mass media and interpersonal communication channels (Wright & Charlett, 1995). The latter, including nonverbal

observations, is thought to be a key factor accounting for the shape of the curve and the speed of diffusion (Gatignon & Robertson, 1985; Mahajan et al., 1990; Rogers, 2003).

Using this pattern of adoption in an eco-system (i.e., the market), according to Rogers (2003), penetration will follow a normal distribution consisting of five groups of adaptors: (a) innovators (2.5%), (b) early adopters (13.5%), (c) early majority (34%), (d) late majority (34%), and (e) laggards (16%). The growth rate of this trend usually takes the form of an S (sigmoid) curve, with slow adoption at the beginning of the cycle, rapid adoption as the population expands, and then slower growth as full penetration nears (Chandrasekaran & Tellis, 2007; Lotfi et al., 2014; Michalakelis, Varoutas, & Sphicopoulos, 2008). The sigmoid curve is derived as the mathematical integral of a statistical curve; the normal curve is assumed as the base in this case. The concept of an S curve to reflect growth is common in innovation research, though other curves can also be used for modeling (Mahajan & Peterson, 1985). Markus (1987) argued that when an innovation becomes more valuable when more people adopt it (e.g., network effect; Yoo,2015), then an exponential curve might represent a better adoption model. In either case, there is no guarantee that the adoption of an innovation will reach these groups; innovations can die out at any stage of the adoption process (Rogers, 2003; Sahin, 2006).

Rogers' model is designed to apply to social systems based communication among social system members in a progressive pattern of knowledge, persuasion, decision, implementation, and confirmation. The process was characterized by Rogers as an uncertainty reduction process based on five specific attributes: relative advantage, compatibility, complexity, trialability, and observability. The model can be applied to an

entire market for a product or service in macro-economic fashion (Chandrasekaran & Tellis, 2007; Christensen, 1997; Christensen & Overdorf, 2000; Christensen & Raynor; Moore, 1991; Utterback, 1994) or it can be used to analyze the characteristics of specific social systems at the organizational level. In the latter case, the focus of this analysis can be used to gain insights into the factors that are influencing adoption within an organization or across an industry. This analysis has been applied to technology adoption in education (Dooley, 1999), health services (Greenhalgh, Robert, Bate, Macfarlane, & Kyriakidou, 2008; Meyer & Goes, 1988), agriculture (Hall, Dunkelberger, Ferreira, Prevatt, & Martin, 2003), service organizations (Greenhalgh et al., 2008), and many others (Rogers, 2003). These two alternative views can overlap in the case where products are offered in a B-to-B marketplace where each organization has their own internal adoption characteristics and curve (Attewell, 1992; Lundblad, 2003; Rogers, 2003)

One of the core assumptions in Rogers work at the organization level is the concept of choice (Lundblad, 2003). Given a specific new technological innovation, the members of a social system will choose to accept or reject it either actively or passively. This process occurs over time based on communication between the members of the social system (Rogers, 2003). Rogers indicates that the three types of innovation decisions within an organization are optional, collective, and authority. There are critical choices within an eco-system, such as technology selection in a large corporation, that are typically not left to the discretion of individuals (Attewell, 1992). Decisions are made based on organizational review, and new innovations are mandated for employees in a

top-down (authoritarian-style) process. Employees will have little input on the timing and nature of the innovations that are adopted by the organization (Eveland & Tornatzky, 1990). In this scenario, the PERT chart for the project, rather than a normal distribution curve, can be better used to model adoption.

While the Rogers model has descriptive capabilities with respect to how markets work, it also has limitations when it comes to accelerating the rate of diffusion or forecasting. Wright and Charlett (1995) made the point that Rogers approach has three limitations. First, empirical evidence shows no consistent linkage between personality traits and adaptor category. Rogers (2003) spent considerable time describing the detailed attributes of each group of adopters, yet the empirical research does not show a reliable correlation (Wright & Charlett, 1995). Consumers can be early adopters for some product categories and be laggards for others. This makes it difficult to target early adopters, as a category, to speed the process of diffusion. Second, the model is based on a normal distribution around the mean time of adoption, so the calculation of the mean and standard deviation of the categories cannot take place until the diffusion process is complete. Third, the level of interpersonal communication is limited in some markets, and without being able to identify specific early adopter populations, only mass communication is feasible. Rogers model is much more of a descriptive model then a predictive tool (Wright & Charlett, 1995).

Several other models have been put forward that purport to help with predictability and forecasting. One of the most popular is the Bass (1969) model, which is also a diffusion model based on communication. The model focuses on two forms of

communication: mass media and word of mouth. In this view of the social system there are only two types of adopters: those that are influences by mass media (external) and those that are influenced by word-of-mouth (internal). Bass refers to these groups as innovators and imitators, respectively (Bass, 1969; Mahajan et al., 1990; Ofek, 2016). The Bass model also contains an S (sigmoid) curve to model adoption (Wright & Charlett, 1995). The model requires estimating just three parameters to build forecasts: the coefficient of external influence (p), the coefficient of internal influence (q), and the market potential. Mahajan et al. (1990) and Ofek (2016) provide insights into sources and considerations when estimating these parameters. These researchers also indicated that the Bass model has been used for forecasting the diffusion of innovation in retail service, industrial technology, agriculture, education, pharmaceuticals, and consumer durable goods (Akinola, 1986; Bass, 1969; Kalish & Lillien, 1986; Lawton & Lawton, 1979; Nevers, 1972; Tigert & Farivar, 1981). Wright and Charlett (1995) confirm a number of other successful applications and a growing following. Mahajan et al. (1990) also provide a detailed analysis of several published variations on the Bass model that add variables to consider the effect of other forms of markets and communication.

While these models, or variations, appear to be the most popular in the literature, they are by no means the only models available. Hall and Khan (2003) and Peres et al. (2010) provided a thorough review of other models, considerations, and future research directions. This research study is based on 40 years of market share results for a technology industry. Since this is historical information, rather than a market forecast, it should be possible to approximate the mean and standard deviation of the normal

adoption curve. In this scenario, Rogers model can be used to forecast diffusion, without estimating the coefficients required in the Bass model. This analysis is focused on Rogers model moving forward.

Moore (1991) discussed the existence of a *chasm* between early adopters and the early majority in Rogers model. Moore indicated that this is because early adopters and early majority users are distinct audiences with different needs (Chandrasekaran & Tellis, 2007; Chandrasekaran & Tellis, 2012). Early adopters are looking for a competitive advantage and willing to accept more risk to accomplish this goal. On the other hand, early majority users are looking for demonstrable organizational value with a high likelihood of success (Moore, 1991). This suggests that once firms establish traction with early adopters, they will need to change their market offering and messaging to meet the needs of the early majority. Moore (1991) suggested three techniques: pick a specific initial target audience in the early majority to focus on, offer a product that precisely meets the needs of that audience, and be very specific about the messaging and value proposition. One interesting observation about Moore's (1991) work is that it seems to be focused on a macro-economic diffusion process, yet the analysis is focused on the outcome for a specific supplier, and what each supplier can do individually to cross the chasm. Rogers (2003) model described the interactions between producers and consumers in a social system, based on patterns of communication, rather than the actions of a single supplier to the social system.

The chasm discussed by Moore (1991) is a conceptual model supported by anecdotes rather than detailed scientific investigation. However, a similar diffusion

scenario has been observed and explored in the academic literature. The pattern consists of an initial peak in adoption, which predates a trough of substantial depth and duration, that is followed by increases sales that eventually exceed the initial peak. This pattern has been defined as a saddle by Goldenberg, Libai, and Muller (2002). This pattern of diffusion has also been studied, confirmed, and analyzed by Goldenberg et al. (2002), Golder and Tellis (2004), Mahajan and Muller (1998), Muller and Yogev (2006), Vakratsas and Kolsarici (2008), Van den Bulte and Joshi (2007), Libai, Mahajan, Muller (2007), and others.

To explain this scenario Goldenberg et al. (2002) discuss a dual market phenomenon that is similar to the explanation offered by Moore (1991). Golder and Tellis (2004) Chandrasekaran and Tellis (2007) suggest an alternate explanation based on the informational cascades work of Bikhchandani, Hirshleifer, and Welch (1992, 1998). In this scenario, early consumers choose to buy a product based on its merits. Customers that follow their lead, choose to buy a product based on the implicit endorsement of earlier adopters, rather than their own personal assessment of the products merits. As the number of adopters grows, the adoption rate accelerates more rapidly than it would if each participant were making their own personal assessment. Cascades of this type are fragile and small doubts in the market or other disturbances can disrupt the process and cause a negative cascade (e.g. a chasm). Golder and Tellis (2004) and Chandrasekaran and Tellis (2007) offer a third potential explanation based on macro-economic forces. An economic slow-down can trigger a decline in *discretionary* spending on new products; thus, a chasm could be the result of the stage in the business cycle (Deleersnyder,

Dekimpe, Sarvary, & Parker, 2004), rather than the specific point on the product lifecycle curve. The research of Golder and Tellis (2004) confirms that both informational cascades and economic health can affect the adoption of new products and create a break in the continuity of the traditional bell-shaped curve of Rogers (2003). This research study is focused on the form of innovation that resulted in market share leadership at each stage in the lifecycle. The results should indicate whether a change in innovation focus led to leadership in any particular phase.

The work of Rogers (2003) was based primarily on technological innovation applied to new product development. Utterback and Abernathy (1975), expanded on this concept to show that when a new product category begins to emerge around a class of innovation or discontinuity, there are often many market entries with competing approaches. Over time, market activity tends to consolidate around a dominant design. Once a dominant design is established in the market, and the market begins to mature, the focus of innovation shifts from product innovation to process innovation. This shift can help establish efficiencies and economies of scale that lead to a competitive cost advantage. Tushman and Anderson (1986, 1990) explore the relationship between technological discontinuities (e.g. a shift to a new S curve), followed by a period of intense competition, which leads to the establishment of a dominant design and industry standard. Tushman and Anderson (1986, 1990) assert that the discontinuities never become the dominant design, and dominant design lags behind the leading technical frontier. The A-U model, developed by Utterback and Abernathy (1975), and refined by others, is still a cornerstone of innovation theory today (Akiike, 2013).

The OECD, an international research organization that represents 36 member countries, and over 70 non-member countries, recognized only technological product or process innovation prior to 2005 (OECD, 1997). This definition of innovation is consistent with the A-U model. In 2005 the OECD updated their definition to recognize four types of innovation: product, process, marketing, and organizational innovation; and de-emphasized technology as the primary source of product innovation (OECD, 2005). This change was due in part to the emergence of services as a form of product. In the most recent version of the Oslo manual (OECD, 2018), the OECD now highlights product and business process innovation, with business process innovation spanning the supporting functions of production, distribution, marketing, information systems, management, or business process. Schumpeter (1934), a pioneer of innovation theory in economics (Śledzik, 2013), suggested that innovation could take five forms: (a) product/product enhancement, (b) embracing new methods of production or sales, (c) opening a new market, (d) finding new sources of raw materials or supply chain partners, and (e) creating a new industry structure. This aligns well with the current OECD definition of innovation, but expands well beyond the innovation framework that is used in the A-U model. A more detailed discussion regarding the definition of innovation is included in the literature review.

Others in research and practice have presented other options for innovation which include: business model innovation (Foss & Saebi, 2017; Zott et al., 2011), marketing innovation (Gupta & Malhotra, 2013; Michel, 2014; Zehr, 2016; Zhou et al., 2005), and other forms of innovation frameworks (Keeley, 2013; Moore, 2005). Some of

these forms of innovation have been shown to produce far greater returns than product or process innovation (Lindgart et al., 2009).

In this research project, an expert panel is used to build consensus on the leaders in a technology industry at each stage in the lifecycle, the forms of innovation available to them, and the form used by each to establish leadership. The results could be used to extend the A-U model to other forms of innovation recognized by the OECD, Schumpeter, and others.

Literature Review

Importance of Innovation

Schumpeter (1934) argued that economic growth was a function of creative destruction which stems from competition as entrepreneurs bring new offerings to market and change/renew the composition of markets. He believed that the consumer was passive in the process, and in the absence of innovation, markets would become stagnant. Van de Ven (1986), Zaltman, Duncan, and Holbek (1973), and Rogers (2003), described innovation as a new idea, which may be a recombination of old ideas, a scheme that challenges the present order, a formula, or a unique approach which is perceived as new by the individuals involved. Drucker (2002) believed that innovation was the work of entrepreneurs as well, and defined it as an activity designed to create purposeful, focused change in an organizations economic or social potential. Drucker (1998) also described the most fertile ground for innovation inside an existing organization as unexpected occurrences, incongruities, process needs, industry/market changes; while in the external

environment innovations were most likely to be found in demographic changes, new perceptions, or new knowledge.

Vincent (2005) observed that numerous studies in economics, organizational theory, strategic management, and marketing have focused on studying innovation. The literature contains strong evidence that technological innovation in manufacturing firms is a primary source of industrial competitiveness and national development (Landau & Rosenberg, 1986; Tidd, 2001; Zaltman et al., 1973). Fagerberg, Srholec, and Verspagen (2010) outlined research that illustrates innovation can be used by nations, even the poorest, to evolve and compete globally.

Innovation is thought to provide organizations with a means of creating a sustainable competitive advantage and is an essential component of economic growth (Brown & Eisenhardt, 1995; Mandel, 2004). Innovation is a key strategic activity undertaken by organizations that provides them with a mechanism for better alignment with market conditions (Schoonhoven, Eisenhardt, & Lyman, 1990). Reed and DeFillippi (1990) and Barney (1991) also noted that innovation is a mechanism by which organizations can draw upon core competencies and transition these into performance outcomes critical for success. Nussbaum, Brady, and Berner (2005) and Garvin and Levesque (2006) explore the critical role creativity, innovation, and entrepreneurship play in market leadership. Research shows that innovation has been responsible for 80% of U.S. economic growth since World War II (Atkinson, 2011) and continues to be a driving force behind economic expansion and wealth creation (Bristow & Healy, 2018). Specific examples with respect to U.S. technology company leaders were provided in Chapter 1.

Perspectives on Innovation

There is usually a distinction drawn between invention, innovation, and imitation (Ahuja & Morris Lampert, 2001; Boons & Lüdeke-Freund, 2013; Fagerberg, 2003). In Schumpeter's publications (1934, 1939, 1942) the process of innovation consists of three dimensions: (a) invention, (b) innovation, and (c) diffusion. This view has been expanded over time to consist of (a) invention, (b) innovation, and (c) imitation, with (d) diffusion reflecting the ultimate rate of adoption of an innovation (Bessen & Maskin, 2009; Brozen, 1951). An invention is the first occurrence of an idea for a discovery, device, or process; on the other hand, an innovation goes one step further with commercialization or adoption of the new idea (Fagerberg, 2003). The process of diffusion occurs as others embrace innovations in the marketplace (Rogers, 2003). There are many barriers to the diffusion described by Rogers (2003) and others (Wright & Charlett, 1995), and many innovations are never widely adopted. Imitation occurs when some aspect of an existing product, service, or process, is replicated by another organization in a closely related market or industry (Fagerberg, 2018).

Invention and innovation can be closely related, especially in organizations that have a formal research & development process. Still, invention is much more common than innovation. To illustrate further, an investigation of the pharmaceutical industry from 1980 to 1985, showed that of the 1,573 patents filed only 18.3% eventually became products (Chandy, Hopstaken, Narasimhan, & Prabhu, 2006). Bradley and Weber (2004), drawing on data from the Pharmaceutical Research and Manufacturers Association

(PhRMA), also reported that only one of every 10,000 new compounds tested in the laboratory becomes an approved drug.

Even when products make it to market, there is no guarantee of commercial success. Of the pharmaceutical inventions that did make it to market in the research cited by Bradley and Weber (2004), only 30% received enough commercial success to even recover development costs. Research on venture capital funds performed by Harvard University indicate that 75% of investments do not return investor capital (Gage, 2012). Startups that receive venture capital are a select group of companies, selected by professional investors, based on the potential for success in the market. When looking at the overall failure rates of new business ventures, Wagner (2013) shared numbers from Bloomberg, which indicated that eight out of ten fail within the first 18 months; Carmody (2015) found that 96% of businesses fail within 10 years; and The Bureau of Labor Statistics research show that 44% of business fail within 5 years (Bureau of Labor Statistics, 2016). The latter numbers, while lower, are also based on businesses that have employees and excludes sole proprietors from the study (Waring, 2017); even though sole proprietors represent 70% of the business population (Beesley, 2013). When looking at innovation within an existing business, Nussbaum et al. (2005) reported that 96% of all new internal projects fail to meet or beat targets for return on investment. This underscores the fact that even though innovation is essential for economic growth (Schumpeter, 1934), entrepreneurship based on innovation is fraught with peril and there is certainly no guarantee of success.

Freeman (1974), Director of the Science Policy Research Unit (SPRU), building on Schumpeter's work, changed the focus of innovation from being an economic variable based on the factors of production, to *the process* of innovation, and explored the role of formal research and development in creating technological innovation. Freeman, like Schumpeter (1934), believed that innovation requires commercialization rather than just invention. However, Freeman also associated innovation with technological innovation rather than the wider spectrum of elements proposed by Schumpeter. This view of innovation has been characterized by Anderson and Tushman (1990) and Campbell (1969) as a sociocultural evolutionary process of variation, selection, and retention. Godin (2006), described this evolution of thinking from innovation as an economic variable, to innovation as a source of business value.

Fagerberg (2003) and Fagerberg (2018), in an extensive search of the literature, identified several ways to characterize innovation. First, innovation can be considered a process consisting of an initial invention, followed by a series of complimentary incremental innovations. In fact, it may not be possible to realize the full economic value of an initial innovation, without further incremental innovation (Bessen & Maskin, 2009; Teece, 1986). This view is consistent with Christensen's theory of disruptive change (Christensen, 1997). This should not be construed to mean that innovation is a linear process driven by systematic research and development (R&D). This linear approach is embraced by many firms (Godin, 2006); however, Kline and Rosenberg (1985), made the point that firms start by combining existing knowledge, and only when that fails, will they invest in new discovery (science). R&D doesn't have to be the starting point for

innovation, R&D (internal or external) can be called into service at in point in the innovation process. In a study of more than 1,800 successful innovations tabulated by Marquis (Tushman & Moore, 1988), almost three-quarters were reported as having been initiated as the result of perceived market needs, and the remainder stemmed from a technical opportunity (Kline & Rosenberg, 1986). Von Hippel (2005) and Lundvall (2016) have also shown that user experience, rather than science, is a more important source of innovation. In addition, the failure of initial innovations can lead to new (more important) discoveries in a circular (incremental) discovery process. This type of pattern, often referred to as a non-linear process (Alekseevna, 2014), is one of the primary tools used by entrepreneurs trained in the business model canvas technique (Osterwalder & Pigneur, 2010). This process requires the firm to have the absorptive capacity to identify new discoveries externally and then embrace them to generate innovations internally (Cohen & Levinthal, 1990; Lau & Lo, 2015). The ability to quickly experiment, evaluate, and then pivot based on the results, is a fundamental tenant (Blank, 2013; Ries, 2011). This concept is also fundamental to non-linear methodologies such as Agile, which has supplanted the linear waterfall model that has been widely used in software development for decades (Brhel, Meth, Maedche, & Werder, 2015; Dingsøyr & Lassenius, 2016). Alekseevna (2014) provided a detailed discussion of the emergence of non-linear models. These methods have not made linear models obsolete, but they have become mainstream for many innovation-oriented activities.

Second, innovation can be judged based on the magnitude of the discovery involved. A small incremental change along an existing S curve, while important, should

not be given the same consideration as a disruptive innovation that leads to a new S curve and industry structure. This also ties naturally to the work of Christensen (1997) and Anderson and Tushman (1990). The topic of disruptive innovation will be given more attention later in this chapter.

Third, innovation can be identified by the type of innovation. As discussed in Chapter 1, historically it was common to think of innovation in terms or product or process innovation (Marzi, Dabić, Daim, & Garces, 2017)., with technological innovation playing a pivotal role in bringing about change. Yet, over the last century, many of the most important innovations have been related to distribution rather than production (Chandler & Hikino, 2009). In recent times we have seen innovative platform business models used by Amazon, Uber, Airbnb, and others, disrupt entire industries (Geissinger, Laurell, & Sandström, 2018; Riemer, Gal, Hamann, Gilchriest, & Teixeira, 2015; Teixeira & Brown, 2018a; Teixeira & Brown, 2018b). This assessment was shared by Distanont and Khongmalai (2018), who concluded, based on the prior work of Bessant and Tidd (2007), Schilling (2010), and Smith (2006), that innovation tends to be classified by the type of innovation, product or process, the degree of change involved, radical versus incremental, and whether the innovation is technological in nature.

There is discussion in the literature about the significance of an innovation and the ability to deliver value for the firm or clients (Box, 2009; Souitaris, 1999). In particular, a specific innovation can be new to the world, new to the industry, or new to the firm. The minimum requirement from the standpoint of OECD (2018) is that an innovation must be new to firm. In the resource-based view of business strategy

discussed earlier; sustainable competitive advantage comes from creating strategies that leverage core competencies (David & David, 2017). Core competencies are capabilities that are valuable, rare, difficult to imitate, and non-substitutable (Hitt et al., 2016). In other words, core competencies, by definition, are unique to the firm. It would be unusual for an innovation that is new to the firm, but not novel for the industry, to be the source of competitive advantage. This is certainly true at the industry level, market parity would be the best possible outcome (Harmon & Castro-Leon, 2018). If the objective of the firm is market leadership, then a primary goal is to find innovations that are new to the market or industry, at a minimum, with the ultimate goal of finding significant innovations that are new to the world. Kim and Nelson (2000) and Kline and Rosenberg (1986) showed that incremental innovations that lead to parity, can serve as the foundation for additional industry leading incremental innovations, that eventually establish leadership and create economic value.

Disruptive Innovation

Christensen (1997), Christensen and Overdorf (2000), and Christensen and Raynor (2003) outlined the process of disruptive innovation, a process where a new innovation shifts an industry from an existing S curve, which is receiving just incremental innovation (Goldberg, Goddard, Kuriakose, & Racine, 2011) along an existing curve, to a disruptive innovation which moves the industry to an entirely new S curve. Consistent with the theories of Rogers (2003), Utterback and Abernathy (1975), and Tushman and Anderson (1986, 1990), movement along the new S curve, once a disruption occurs, starts with a number of competing designs, which consolidate into a dominant design, and finally

results, once again, in incremental innovation along the new S curve as the market matures. Disruption usually occurs with an inferior product offering at the lower end of the market (Christensen, 1997). As the function of the product improves, and more mainstream users embrace it, an increasing number of users move to the new diffusion curve (Christensen, Raynor, & McDonald, 2015). One important aspect of this effect is that disruptive innovation tends to favor new entrants rather than incumbents. Existing market leaders are invested in their customers and systems and would prefer to evolve existing offerings rather than toss them aside and start over (Christensen, 1997). New market entrants do not have the same types of constraints based on existing customer base, legacy products, or systems that need to be protected. This creates the opportunity for leadership change, and new market structure, even when the market has dominant players and forces at work. Porter (1985, 1990) described how this process has been used to win a competitive advantage in international markets as well.

Christensen (1997) first discovered this market effect while studying the competitive evolution of computer disk drive manufacturers, and mechanical excavators, as subsequent generations were released to the marketplace. Examples of this theory at work can also be found in the personal computer market (Christensen et al., 2015), the movie rental business (Chatterjee, Barry, & Hopkins, 2016; Rothaermel, 2018), the smartphone industry (Yoffie & Baldwin, 2015), social services (Christensen Institute, n.d.), and an entire generation of Internet-centric enterprises (Whitefoot, 2017). Amazon, which started as an eCommerce book retailer pre-bubble on the Internet, has evolved into a technology-enabled broker between buyers and sellers online (Wells, Danskin, &

Ellsworth, 2018). This has helped create the widespread disruption of traditional brick and mortar retailers. This "retail apocalypse" is well documented in the business press (Reddy, 2019). eCommerce now accounts for almost 10% of retail sales in the United States (Dennis, 2018) and Amazon is responsible for almost 50% of online retail sales (Thomas & Reagan, 2018). Amazon Web Services, a rapidly growing division of Amazon, offers portions of its internal technology stack to other online companies (Wells et al., 2018). Amazon leads Microsoft, Google, IBM, and others, in that space (Novet, 2018); however, since Amazon is a consumer of technology, rather than a source of new technology, it is not clear if this represents a movement along an existing S curve, with the incumbents scrambling to close the gap, or a movement to a new S curve for cloud-based computing services. The activity around Internet-based businesses was discussed earlier. The latest disruptive examples are Uber, Airbnb, and Etsy (Teixeira & Brown, 2018a; Teixeira & Brown, 2018b), which make use of a technology-based platform, rather than a traditional pipeline business model (Van Alstyne, Parker, & Choudary, 2016).

Categories of Innovation

Past scholars have often found it necessary to categorize and distinguish innovations in order to understand the true nature of the construct (Downs & Mohr, 1979). Studies focused on innovation generation have primarily used the following typologies: (a) product versus process and (b) radical versus incremental (Vincent, 2005). OECD expands on both of these typologies in the Oslo manual (2018). Disruptive innovation has already been covered in this analysis.

Product, process, and differentiation. OECD has been researching and publishing guidelines on research and development (R&D) data since the first edition of the Frascati manual in 1963 (OECD, 2015). The creation and diffusion of new technologies is central to the growth of output and productivity (Schumpeter, 1934). R&D and scientific discovery were, at that time, considered the front-end to the linear innovation process (Kline & Rosenberg, 1986). Tracking R&D played a critical role in tracking innovation as an essential input (OECD, 2015).

Over time, industry experts came to understand that R&D was only one important indicator and more information was required to capture the level of innovation (OECD, 1992). The OECD outlined three current sources of input on innovation and technology: (a) R&D activity, (b) patent data, and (c) bibliometric data on scientific publication (OECD, 1992). The linkage between R&D inputs, and innovative output, are uncertain at best, especially given the recognition of non-linear models for innovation (Alekseevna, 2014; Mahdjoubi, 1997). There are at least two other limitations to relying on patent data. First, not every firm secures patents to protect their new ideas. Trade secrets and speed to market are also common competitive techniques. Second, innovation requires commercialization, and the overwhelming majority of patents do not become commercial products (Kline & Rosenberg, 1986). Bibliometric data can indicate the changing shape of research trends, but is a poor indicator when it comes to the innovation process or commercialization (OECD, 1992). The research of Pavitt (1982) also showed that R&D spending underestimates the amount of innovative activity in small firms, while patent data underestimates the level of innovative activity in large firms.

To help address these limitations, the OECD created a working group of technical experts from member countries and published the first edition of the Oslo manual in 1992 (OECD, 1992). The goal was to provide a set of tools, beyond the existing ones, to capture and interpret innovation data. The Oslo manual is now in its 4th edition, which was published in 2018 (OECD, 2018). The definition of innovation, and the types of innovation recognized, evolve with each subsequent version based on research, experience, and member feedback (OECD, 2018).

The Oslo manual outlines two broad approaches to capturing innovation data. The first approach is to identify significant innovations based on the input of experts, uncover the firm that initiated the innovation, and then try to identify critical factors. The second is to survey all firms, take stock of their innovative behaviors, and extrapolate that into macroeconomic trends (OECD, 1992). The Oslo manual takes the latter approach (OECD, 2018). In this research study, the former method is used based on market leadership. This approach is taken because historical results are available and this information is more definitive rather than just indicative.

The first version of the Oslo manual is intended to focus only on technological innovations in businesses at the firm-level (OECD, 1992). The context is manufacturing activity that takes place in a pipeline business (Van Alstyne et al., 2016). In this early body of work, a service is not considered to be a product. OECD started with the forms of innovation first proposed by Schumpeter (1934) as: (a) the introduction of a new good, (b) the introduction of a new method of production, (c) the opening of a new market, (d) the conquest of a new source of supply of raw materials or semi-manufactured goods, or

(e) the re-organization of an industry. The OECD selected the first two categories as being the only example of proper technological innovation (OECD, 1992). Thus, the OECD defined only technological product or process innovation in the first edition of the Oslo manual. The definition provided by the OECD describes a series of scientific, technological, organizational, financial, and commercial activities that are launched in the market as product innovation, or used within a production process as process innovation. This aligns with the definition of innovation used by Anderson and Tushman (1990), Suarez and Utterback (1995), Utterback and Abernathy (1975), Utterback and Suarez (1993), and the A-U model. This also supports the manufacturing-centric view of innovation that has been the mainstay of commerce for hundreds of years (Von Hippel, 2005).

The first version of the Oslo manual outlines the distinction between major disruptive product innovation and incremental product innovation. There is also a distinction made between product innovation and product differentiation. A product differentiation is a change made to a product, or an element of the marketing mix, that offers greater value to customers, but does not constitute an entirely new product (OECD, 1992). Using this definition, the creation of the first smartphone would be a major product innovation, adding more memory or screen resolution would constitute an incremental innovation, and offering a new color or price point would be differentiation.

The second edition of the Oslo manual (OECD, 1997) also contains a focus on technological product and process (TPP) innovations. The definition of a product is expanded to cover both products and services, consistent with the system of national

accounts (United Nations, 1993). In current marketing literature, a product is often described as a physical product, service, information, or experience (Kotler & Armstrong, 2017). Products can be either technologically new or just technologically improved. The second edition of the Oslo manual also states that technological process innovation can occur in supporting activities such as purchasing, sales, information technology, and others; however, the focus is still on technology applied to products and the manufacturing of products. The view of production processes in the second edition was expanded to include the use of technology to improve the delivery of products and services. This aligns with Schumpeter's fourth form of innovation (Schumpeter, 1934). This version of the manual referenced organizational innovation for the first time, but also notes that it is distinct from technological product and process (TPP). There is still a distinction drawn between differentiation and TPP; TPP requires an objective improvement in the performance of a product or the way it is delivered (OECD, 1997). Overall, with the exception of including delivery methods, which could be considered an extension of the production process, the second edition is still consistent with Utterback and Abernathy (1975).

The third edition of the Oslo manual (OECD, 2005) defined a product as a product or service, but does not require a technological innovation, just a significant change. The primary concern that drove this change was that service providers might see technological innovation as requiring the use of advanced technology (OECD, 2005). The view of a product was expanded to reflect an augmented product consistent with Kotler and Armstrong (2017). The types of innovation were expanded to product, process,

marketing, and organizational. Just as in the second edition, production process innovation included changes to production *or* delivery methods. A marketing innovation can take place within any aspect of the marketing mix, consistent with Zehr (2016). Changes in the marketing mix can open new markets, and organizational innovation can lead to the re-organization of industries, which align with Schumpeter's forms of innovation (Schumpeter, 1934). The recognition of organizational innovation is important because it reflects a growing awareness of business model innovation (Foss & Saebi, 2017; Zott et al., 2011) which will be discussed in a later section. The recognition of four types of innovation, rather than just technological product and process innovation, represented a significant break with the approach used by Utterback and Abernathy (1975). However, it is much more consistent with the views of Porter (1990). It is also similar to the framework used by Tidd and Bessant (2018) which highlights product innovation, process innovation, position innovation, and paradigm innovation. The latter two categories of innovation are just more restrictive versions of marketing innovation and organizational innovation.

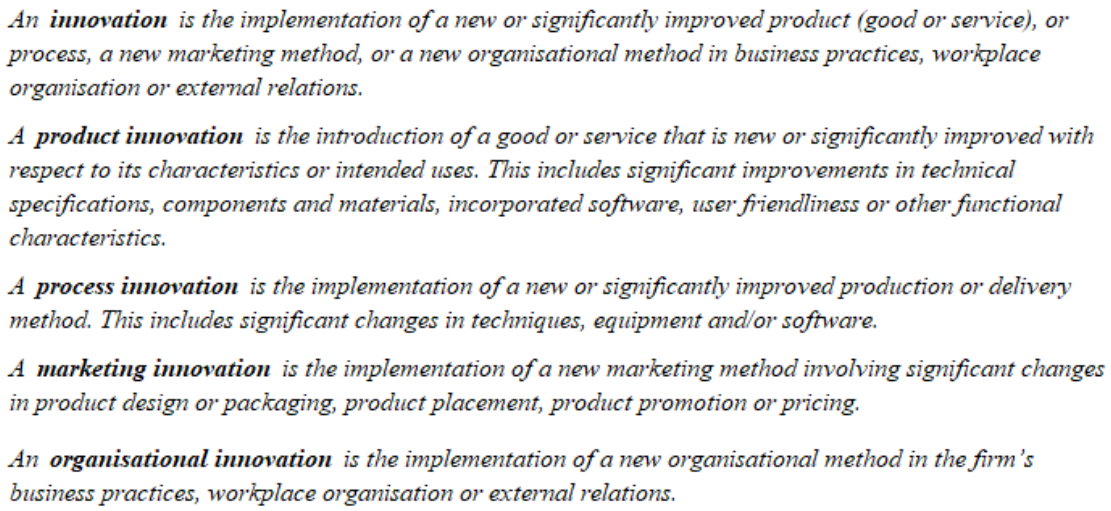


Figure 1. The forms of innovation recognized in the fourth edition of the Oslo manual. Adapted from "Oslo manual 2018: Guidelines for collecting, reporting and using data on innovation, 4th edition," by Organization for Economic Cooperation and Development, 2018, Paris, France: OECD Publishing. Public domain.

The fourth edition of the Oslo manual defined business innovation in similar terms as earlier versions; however, it did reflect a slightly different view of the firm. The fourth edition described a product, which can be a product or service, and support activities designed to produce and deliver products and operate the organization more effectively. In this description, information represented a form of product, and experience represented a form of service. The support activities described were all cast as process innovations (OECD, 2018). This treatment resulted in two broad categories of innovation, product and process, with process innovation broken into six sub-categories: (a) production processes, (b) distribution and logistics, (c) marketing and sales, (d) information and communication systems, (e) administration and management, and (f) product and business process development.

Product innovation, along with the process innovation category a, align well with Utterback and Abernathy (1975). The addition of process innovation, category b, align well with the second edition of the Oslo manual. The inclusion of process innovation category c, and process innovation category e, align with the third edition (OECD, 2005), except that in earlier versions, there are no restriction on process innovation for either category. Process innovation, category e, reflects the more significant role of information systems and communication technologies in economic activity. Process innovation, category f, is a stand-alone category for innovations related to becoming more innovative. Category d of process innovation did not exist when the original research for Utterback and Abernathy (1975) took place. The first PC was not introduced until 1975 (Reimer, 2005; Steffens, 1994), and the first commercial web browser was not available to the public until 1994 (Yoffie & Kwak, 2001).

The fourth edition of the Oslo manual introduced four types of innovation that were not present in the analysis used in the A-U model (Utterback & Abernathy, 1975). This version expands well beyond the categories presented by Schumpeter (1934). The paradigm of marketing and organizational innovation existing only as a form of process innovation is not embraced in the literature. One example of this is business model innovation, an extremely popular topic in the literature since 2000 (George & Bock, 2011; Osterwalder, 2004; Zott et al., 2011), which would be considered a form of organizational innovation. Business model innovation, especially disruptive forms, go much further than just business process changes.

Marketing innovation. One limitation of the fourth edition of the Oslo manual is that marketing is defined as a process. The actual design and specification of products, often a marketing function, is included in product innovation. The other market-facing elements of marketing such as pricing, packaging, and promotion are included in the marketing sub-category of process innovation (OECD, 2018). In the third edition, a distinction is made between innovation and differentiation. The fourth edition makes no mention of differentiation, although that is often a primary function of marketing (Kotler & Armstrong, 2017). It is important to distinguish between the use of innovative marketing methods, and redefining the marketing offering in a way that increases both customer value and product preference (Foroudi, Jin, Gupta, Melewar, & Foroudi, 2016; Halpern, 2010; Ngo & O'Cass, 2013). The challenge with the treatment in the fourth edition is that the market offering that is purchased, can provide more value to the customer, then the underlying device that is being manufactured, or core service being delivered (Davidow, 1986). Kotler (1965) showed that there is a distinct difference between the marketing mix and marketing strategy, and the marketing mix must be adjusted over the lifecycle of a product in order to remain competitive. Zhou et al. (2005), highlight the difference between technological product-based innovation and market-based innovation. Ngo and O'Cass (2013) made the point that technological innovation receives a lot of attention in the literature, while non-technical innovation, in areas such as sales and marketing, often receives much less attention. However, Grimpe, Sofka, Bhargava, and Chatterjee (2017) find that investments in marketing

innovation have at least the same potential to generate superior performance as R&D investments. This point will be developed further with a couple specific examples.

The physical creation of the iPod, an invention and an innovation, is not what made this technology offering successful in the marketplace. The success of the iPod, a physical device, can be attributed to the seamless integration with iTunes, music licensing agreements with the major record labels, affordable pricing on a per song basis, and a strong consumer brand to help accelerate diffusion (Yoffie & Baldwin, 2015). The combination of all these elements, which transformed the physicall device into a compelling consumer market offering, is an example of a marketing innovation. The offering that was shared with the market, and purchased by the customer, did not consist of a device or a process alone.

The sandwich restaurant chain Subway provides another great example. The company was originally started in 1965 by Fred DeLuca and Peter Buck (Griffin, n.d.). The company was not immediately successful, but did enjoy steady growth after adopting a franchising model for expansion in 1975. The original po' boy sandwich was invented in 1929 in New Orleans, Louisiana (Leath, 2014). The product that Subway offers is not that different from its early ancestor. The sandwich consists of lunchmeat and condiments layered between two elongated buns (Foster, 2015). In fact, if the elements of the sandwich were to be modified significantly with technology, this might actually give consumers cause for concern (Boccia, 2019). Subway spent time creating a production line structure to help assemble sandwiches as rapidly as possible. This could have been considered a process innovation when Subway first moved to this model. It would have

been unique to the firm at that point, but certainly not unique to the industry, or new to the world. What ultimately gave rise to Subway's widespread success, was the creation of the $5 footlong (Boyle, 2009). Subway created this offering by reducing retail pricing, increasing volume to generate economies of scale, and then saturating the market with catchy advertising. The result was 289% revenue growth in revenue from 2007 – 2015, compared to only 59% revenue growth from 2000 – 2008, while other competitors were struggling (Berman, 2014). This does not represent a classic case of product innovation or a process innovation, but instead reflects a market-based innovation (Zehr, 2016).

There are many processes involved in both product marketing and marketing communication. In market-oriented firms, marketing often identifies a market need, and then creates a specification that guides delivery (Crawford, 2008). The traditional linear innovation model starts with basic science or technology and then attempts to identify a market need that can leverage it (Pisano, 1997). In either case, this front-end approach can be combined with a structured linear development model such as the waterfall model or a stage gate process (Grönlund, Sjödin, & Frishammar, 2010), or the firm can embrace a non-linear interactive learning process such as the Agile methodology (Martin, 2002).

There is a central tenant in marketing and technology that the best technology, or most advanced device, does not always win; it is the best solution or augmented product that usually prevails (Suarez & Utterback, 1995). Sony Betamax was considered by many experts to be a technically superior product, yet it was eventually overcome in the marketplace by VHS, a technology standard that was licensed to many competing consumer electronics companies. In this case, the superior technology did

not result in a competitive advantage. In fact, the higher price point of the proprietary technology became a negative factor in the marketplace. The offering that won market share and become the dominant platform, had both a lower price point, and access to more pre-recorded movie titles, which increased the value proposition for customers (Suarez & Utterback, 1995; Tellis & Golder, 1996; Yoffie, Aoki, & Debari, 1990).

There are many other types of processes in marketing beyond typical product development processes. The marketing function, in some organizations, is interpreted to mean sales. Sales is often viewed as a process of moving customers through a process of awareness, interest, desire, and action (AIDA) (Hassan, Nadzim, & Shiratuddin, 2015; Michaelson & Stacks, 2011). This is only one sales model, there are many others, and the sales process training industry represented over $4.5 billion in revenue in 2017 (TrainingIndustry.com, 2018). Competitive research can be required for identifying an attractive market segment, setting the performance specifications for a solution, or establishing the price. There are organized processes that can be used for product naming, product testing, product introduction, advertising, and promotion. The role of marketing and sales is to identify commercial opportunities, create market offerings based on variations in the marketing mix, and then bring them to market as effectively as possible (Kotler & Armstrong, 2017). Marketing represents a source of significant market offerings, and innovations, that reach well beyond traditional technological product or process innovation.

Organizational innovation. OECD (2005) defines an organizational innovation as the implementation of a new organizational method in the firm's business practices,

workplace organization, or external relations. OECD (2018) further defined six categories of process innovation: (a) production, (b) distribution and logistics, (c) marketing and sales, (d) information and communication systems, (e) administration and management, and (f) product and business process development. Production processes, along with marketing and sales, are consistent with earlier definitions, with the exception that marketing and sales are usually not considered strictly a process. This concept was explored in more detail in the previous section. Information and communication systems also play a more significant role in operations these days; however, information and communication systems do not always represent a process either (Soto-Acosta, Popa, & Palacios-Marqués, 2016). The category of product and business process development would seem to frame the quest for organizational innovations.

Business model innovation. An extensive literature review by Zott, Amit, and Massa (2010), George and Bock (2011), Ghaziani and Ventresca (2005), and Osterwalder (2004), showed that the number of articles containing the terms business model and innovation has shown rapid growth since 1994. The research of George and Bock (2011) traced the term back to the 1960s (Jones, 1960), although the concept is much older than that (Osterwalder, 2004). Zott et al. (2010), using the EBSCOhost database, identified the term *business model* in 1,203 articles in academic journals; and mentioned in 8,062 non-academic articles from 1975 to 2009. This trend started to gain momentum in the early 1990s and grew rapidly after 1995 as shown in Figure 2.

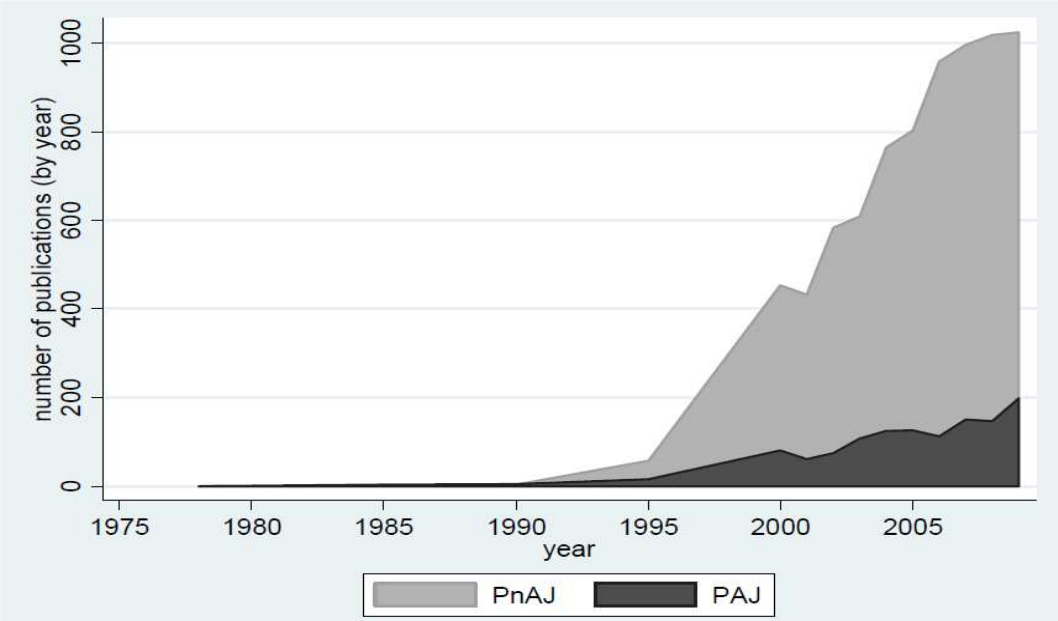


Figure 2. Searches for the term *business model* in non-academic journals (PnAJ) and academic journals (PAJ) from January 1975 – December 2009 based on EBSCOhost Business Source Complete database. Adapted from "The business model: Recent developments and future research.", by C. Zott, R. Amit, and L. Massa, 2011, *Journal of Management, 37*(4), p. 1023. Reprinted with permission.

This growth trend corresponded closely with the emergence of the World Wide Web and the rapid dot com expansion (Ryan, 2010) and implosion that followed closely thereafter. The first commercial web browser was released to the public in 1994 (Yoffie & Kwak, 2001). In spite of the collapse of the dot com bubble, tremendous fortunes were made, and there is a widespread belief that the Internet represented a new economy that would fundamentally change the world (Geier, 2015; Merrifield, 2000; Wood, 2000). In this emerging environment of online commerce, many new business models were tested. Some of these experiments, like Amazon and Google (Frangoul, 2017; Kiesnoski, 2017), turned out well. Almost 5,000 others, like Napster (Beato, 2011) and Boo.com (Wray, 2005), were not quite as fortunate (Clarke, 2015). Green (2004), Soat (2015), and

Gewirtz (2009) provided additional detail on the dot com bubble, the venture capital that was invested, and the value that was lost in the melt-down.

In spite of the large number of articles that discuss business models, Zott et al. (2011), reported that 37% do not define the concept at all, only 44% explicitly define or conceptualize the business model, and the remainder refer to other works. OECD (2018) stated that there is no single recognized definition for business model innovation. This same conclusion has been reached by many other scholars (Massa, Tucci, & Afuah, 2017; Tikkanen, Lamberg, Parvinen, & Kallunki, 2005). Zott et al. (2011) and Wirtz, Pistoia, Ullrich, and Göttel (2015) found a wide range of views in a survey of the literature. The business model was referred to as a statement, a description, a representation, an architecture, a conceptual tool or model, a structural template, a method, a framework, a pattern, and as a set. George and Bock (2011), made a similar observation and suggested that business models in the literature fall into six general categories: (a) organizational design, (b) resource-based view, (c) organizational narrative, (d) innovation form, (e) opportunity facilitator, and (f) transactive structures.

Definitions for the term business model also proliferate in academic textbooks. Rothaermel (2018) described a business model in terms of how the firm intends to make money. Strauss and Frost (2016) expanded on this concept with the idea of long-term sustainability. Barringer and Ireland (2016) described a business model as plan to capture value for stakeholders. This version of the business model consisted of a core strategy which includes mission, target market, differentiation, and scope; resources, composed of core competencies and key assets; financials which captured revenue streams, cost

structure, source of funds; and operations with product, channels, and key partners. This aligns with the concept of the business model template proposed by Osterwalder and Pigneur (2010) and discussed later in this section. Barringer and Ireland (2016) also outline the distinction between standard business models and disruptive business models. The latter category were linked to the concept of disruptive innovation discussed earlier (Christensen, 1997; Christensen & Raynor, 2003; Christensen et al., 2015).

In this case, market disruption is based on an innovative business model, rather than using product innovation as the sole disruptive force (Gewirtz, 2009). There were numerous examples pre-bubble on the Internet, where firms offered new to the world products, using new shopping methods, new sources of raw materials, new delivery techniques, and new operating structures, rather than just product innovation. In this small sample alone, there are a wide variety of viewpoints. Zott et al. (2011) provided a more extensive collection of definitions from existing publications as highlighted in Figure 3.

Selected Business Model Definitions

Author(s), Year	Definition	Papers Citing the Definition
Timmers, 1998	The business model is "an architecture of the product, service and information flows, including a description of the various business actors and their roles; a description of the potential benefits for the various business actors; a description of the sources of revenues" (p. 2).	Hedman & Kalling, 2003
Amit & Zott, 2001; Zott & Amit, 2010	The business model depicts "the content, structure, and governance of transactions designed so as to create value through the exploitation of business opportunities" (2001: 511). Based on the fact that transactions connect activities, the authors further evolved this definition to conceptualize a firm's business model as "a system of interdependent activities that transcends the focal firm and spans its boundaries" (2010: 216).	Hedman & Kalling, 2003; Morris, Schindehutte, & Allen, 2005; Zott & Amit, 2007, 2008; Santos, Spector, & Van Der Heyden, 2009; Bock, Opsahl, & George, 2010
Chesbrough & Rosenbloom, 2002	The business model is "the heuristic logic that connects technical potential with the realization of economic value" (p. 529).	Chesbrough, Ahern, Finn, & Guerraz, 2006; Chesbrough, 2007a, 2007b; Teece, 2007, 2010
Magretta, 2002	Business models are "stories that explain how enterprises work. A good business model answers Peter Drucker's age old questions: Who is the customer? And what does the customer value? It also answers the fundamental questions every manager must ask: How do we make money in this business? What is the underlying economic logic that explains how we can deliver value to customers at an appropriate cost?" (p. 4).	Seddon, Lewis, Freeman, & Shanks, 2004; Ojala & Tyrväinene, 2006; Demil & Lecocq, 2010
Morris et al., 2005	A business model is a "concise representation of how an interrelated set of decision variables in the areas of venture strategy, architecture, and economics are addressed to create sustainable competitive advantage in defined markets" (p. 727). It has six fundamental components: Value proposition, customer, internal processes/competencies, external positioning, economic model, and personal/investor factors.	Calia, Guerrini, & Moura, 2007
Johnson, Christensen, & Kagermann, 2008	Business models "consist of four interlocking elements, that, taken together, create and deliver value" (p. 52). These are customer value proposition, profit formula, key resources, and key processes.	Johnson & Suskewicz, 2009
Casadesus-Masanell & Ricart, 2010	"A business model is . . . a *reflection* of the firm's *realized* strategy" (p. 195).	Hurt, 2008; Baden-Fuller & Morgan, 2010
Teece, 2010	"A business model articulates the logic, the data and other evidence that support a value proposition for the customer, and a viable structure of revenues and costs for the enterprise delivering that value" (p. 179).	Gambardella & McGahan, 2010

Figure 3. Prevalent definitions for business model in academic literature and the publications that have referenced/adopted them. Adapted from "The business model: Recent developments and future research.", by C. Zott, R. Amit, and L. Massa, 2011, *Journal of Management, 37*(4), p. 1024. Reprinted with permission.

Osterwalder (2004) evaluated the publications of the most important business model authors and indicated the areas where a particular author contributes. This work is summarized in Figure 4. This study went on to explore the components of a business model offered by the authors and characterized them as either product, business actor- and network-centric, or marketing-centric literature.

Authors	Definition	Taxonomy	Components	Representation Tool	Ontological Modeling	Change Methodology	Evaluation Measures
(Afuah and Tucci 2001; 2003)	X		X				X
(Alt and Zimmermann 2001)		X	X				
(Amit and Zott 2001)	X						
(Applegate 2001)	X	X					
(Bagchi and Tulskie 2000)							
(Chesbrough and Rosenbloom 2000)			X				
(Gordijn 2002)				X	X	X	X
(Hamel 2000)			X				X
(Hawkins 2001)	X						
(Linder and Cantrell 2000)	X	X	X			X	
(Magretta 2002)	X		X				
(Mahadevan 2000)			X				
(Maitland and Van de Kar 2002)			X				
(Papakiriakopoulos and Poulymenakou 2001)						X	
(Peterovic, Kittl et al. 2001)	X		X			X	
(Rappa 2001)	X	X					
(Stähler 2002)			X				
(Tapscott, Ticoll et al. 2000)	X	X		X		X	
(Timmers 1998)	X	X					
(Weill and Vitale 2001)	X	X	X	X			

Figure 4. Summary of the most important business model authors through 2004 as determined by A. Osterwalder. Adapted from "The business model ontology a proposition in a design science approach", by A. Osterwalder, 2004, Doctoral dissertation, Université de Lausanne, Faculté des hautes études commerciales, p. 24. Public domain.

There are two other significant contributions that do not appear in this body of work. Malone et al. (2006) at MIT, working under a grant from the National Science Foundation, examined the performance of 1,000 of the largest US firms to determine which models performed best. In this study companies were divided into 16 different business types depending on two dimensions: (a) what types of rights are being sold, which included: creator, distributor, landlord, and broker, and (b) what type of assets are used, which included: physical, financial, intangible, and human. These 16 possibilities, represented as a 4 x 4 matrix, gave rise to the MIT Business Model Archetypes. They also indicated that only seven of these possibilities are common in large firms today. Two of the possibilities are actually illegal in this country. Their research work determined that brokers and landlords have higher operating income than creators and distributors, and they also had higher market capitalization than creators. In addition, income and capitalization for non-physical types of assets, consisting of financial, intangible, and human assets, exceeded those using physical assets.

In the archetype structure, business models consist of two elements, what firms do, and how they make money. Popp (2011) embraced this taxonomy for business models, but then distinguished between a business model and a revenue model. This work tied revenue models to each distinct business pattern in a business model. Using this conceptual view, there can be multiple business models in use at the same time.

Johnson, Christensen, and Kagermann (2008) and Christensen, Bartman, and Van Bever (2016) described the business model as a four-box framework composed of value proposition, key resources, key processes, and profit formula. Using this model, the

authors demonstrated how a business model was defined and how the elements could be changed to arrive at business model innovation.

Christensen (1997) made the point that large entrenched organizations find it difficult to make this change because they are optimized to serve an existing customer need. The competitive advantage often lies with an innovative firm that can organize resources and processes around a new customer value proposition. Christensen (1997) further outlined two cases where business model innovation is possible. The first is to serve another audience that is currently un-served or under-served. The second is called low-end disruption which essentially drives down price by becoming more efficient. This can include process innovation, but it can also extend beyond production, to resources and culture. Christensen also made the point that business models can be disruptive. Three current examples of businesses that are using disruptive innovation are Uber, Airbnb, and Etsy. These organizations have made the transition from a traditional pipeline, input-process-out manufacturing style business, to serving as technology-enabled service providers, using platform business models (Van Alstyne et al., 2016).

One other conceptual tool that has grown in popularity is the business model canvas (Osterwalder & Pigneur, 2010). This basic construct is used as a foundation by Blank (2013), Ries (2011), and others; and is offered as a preferred methodology for entrepreneurship studies at universities such as Stanford (Osterwalder, 2012). This model provides the fundamental elements required to represent a business model conceptually which include: (a) key partners, (b) customer segments, (c) value proposition, (d) key

activities, (e) channels, (f) revenue streams, (g) cost structure, (h) key resources, and (i) customer relationships, as shown in Figure 5.

This concept appears to be more closely aligned with entrepreneurs rather than researchers. The basic concept is that once this set of elements is defined, and a minimum viable product is created, the entrepreneur can approach the market and decide how well the offering fits based on customer feedback. This feedback is used to adjust the business model, and return to the market for additional feedback, which is called a pivot. This pattern continues to repeat until the market offering is successful, or it becomes clear that there is no viable form that will work. The core concept is to find the winning formula faster, or fail more quickly, without the need for a comprehensive business plan. This collection of tools has become very popular in the entrepreneurial community (Greenwald, 2012), though it can be difficult to apply in large organizations with existing momentum, based on the difficulty of making a complete pivot (Christensen et al., 2016).

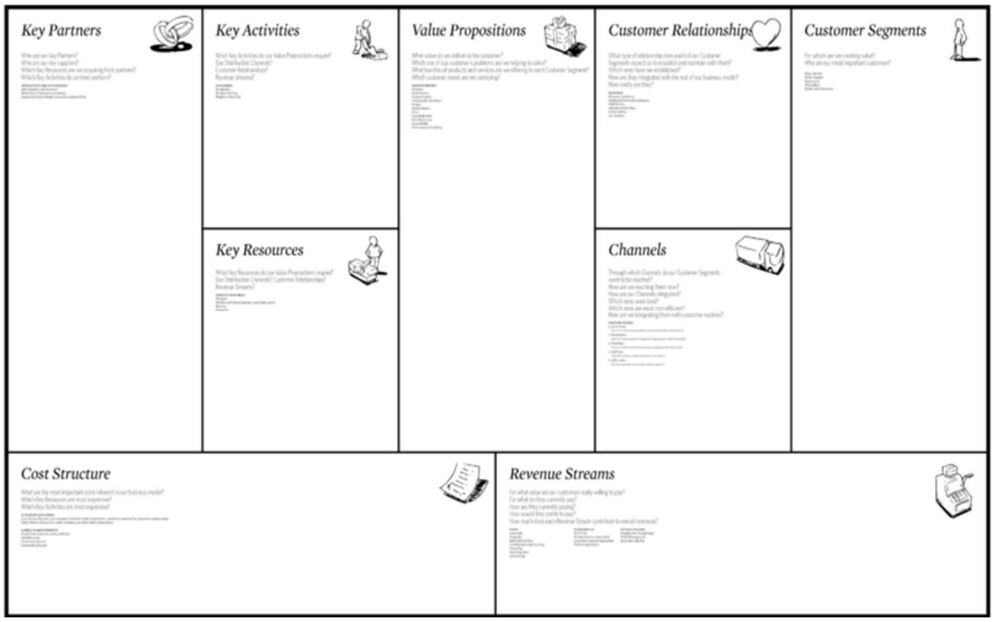


Figure 5. The Business Model Canvas used commonly in university entrepreneurship programs. Adapted from "Business model generation", A. Osterwalder and Y. Pigneur, 2010, Hoboken, NJ: John Wiley & Sons, p. 44. Reprinted with permission.

One common theme that runs through all these business model frameworks is related to resources, processes, customer value, and economic success. These elements are incorporated in the business model canvas, the MIT model, and the Four-Box Business Model Framework. This focus has also been visible in the strategic management literature as well (Hitt et al., 2016; Rothaermel, 2018). OECD (2018) offered the definition provided by Johnson et al. (2008) and confirmed that there is no single unified view of a business model. The Business Model Community (2017) is an online forum that shares theoretical arguments and empirical research related to business models. Based on the discussion in the literature, even though there is disagreement on the definition of a business model, it is well accepted that business model innovation can involve a product innovation, a process innovation, an organizational innovation, or some combination of the three. OECD (2018), does not break out business model innovation as a separate classification, or recommend treating it as such, based on the ambiguity that still exists. This is field of study that is still rapidly evolving (Foss & Saebi, 2017).

Other innovation. Keeley (2013), Michel (2014), Osterwalder (2004), and others explore other sources of innovation beyond traditional product or process-based innovation that is focused on technological innovation. This work does not diminish the value of traditional forms of innovation, it just provides a richer environment in which to search for break-through innovations that lead to sustainable competitive advantage.

Summary and Conclusions

Innovation is described as, a new idea, which may be a recombination of existing ideas, a scheme that challenges the present order, a formula, or a unique approach, which is perceived as new by the individuals involved (Rogers, 2003; Van de Ven, 1986). The spread of an innovation (product, process, or idea) is referred to as diffusion in the marketing literature (Peres et al., 2010). Rogers (1962, 1976, 2003) outlined a model for diffusion of innovations which has become widely established in the marketing literature (Wright & Charlett, 1995). Diffusion follows a normal distribution in Rogers model based on a sigmoid curve (Rogers, 2003). Rogers' model appears to work best with historical data, but can be difficult to use for forecasting applications (Wright & Charlett, 1995). The Bass model is another popular diffusion model in academic literature and appears to have more predictive power (Bass, 1969; Mahajan et al., 1990; Ofek, 2016).

Fagerberg (2003) and Fagerberg (2018) concluded that innovation is generally considered in three ways: (a) as a process consisting of an initial innovation followed by a series or incremental innovations, (b) in terms of whether the innovation is incremental or disruptive, or (c) based on the type of innovation involved. In the first scenario, an innovation is brought to market, a number of initial designs compete for market dominance, the market consolidates on a dominant platform, and then incremental innovation proceeds beyond that point based on the dominant platform (Anderson & Tushman, 1990). Incremental innovations proceed along an existing S curve. Christensen (1997) introduced the concept of a disruptive innovation that moves the

market from an established S curve, to a new S curve, and the same evolutionary pattern occurs all over again. Disruptive innovation tends to favor new market entrants, while incremental innovation favors incumbents.

OECD, an international standards agency, has published the Oslo manual for over 25 years, and each new edition has offered a different definition for innovation (OECD, 1992; OECD, 1997; OECD, 2005; OECD, 2018). The early focus was on technological innovation applied to either product or process innovation in manufacturing organizations. This was consistent with the academic literature at that time. The research of Utterback and Abernathy (1975) showed that firms concentrate on product innovation early in the lifecycle, but once a dominant design is established, the focus turns to process innovation. The latest version of the Oslo manual recognized both product and process organization, but anything beyond product innovation was characterized as a process innovation. This is not in alignment with the views of other subject matter experts. In particular, marketing innovation and business model innovation, both popular topics in practice and the literature, are not reflected in the same fashion in OECD's latest work. In Chapter 3, I discuss the details surrounding research design, data gathering, and analysis.

Chapter 3: Research Method

The purpose of this qualitative e-Delphi research project was to build consensus with an expert panel of innovators and researchers on the forms of innovation used to establish market leadership over the historical lifecycle of a technology industry. Once agreement is established, the results may be added to the A-U model (Utterback & Abernathy, 1975), to create a baseline for non-technological innovation within that framework. In this chapter, I cover the research design and rationale, the role of the researcher, provide details of the methodology being implemented, and discuss issues of trustworthiness.

Research Design and Rationale

Research Question

What is the consensus of an expert panel of innovators and researchers on the forms of innovation that were used by competitors to establish market leadership over the historical lifecycle of a technology industry?

The general problem was that there is no consensus on the form(s) that non-technological innovation can take. The second edition of the Oslo manual (OECD, 1997) recognized technological product and process innovations. The definition of a product was expanded to cover both products and services. The third edition of the Oslo manual (OECD, 2005) recognized product, process, marketing, and organizational innovation. The role of technology was de-emphasized to accommodate products offered by services companies. The fourth edition of the Oslo manual (OECD, 2018) recognized product or process innovation. Process innovation was re-defined to include (a) production processes,

(b) distribution and logistics, (c) marketing and sales, (d) information and communication systems, (e) administration and management, or (f) product and business process development. The second version aligns with the traditional A-U model, the third extends beyond the A-U model by including marketing and organizational innovation, the fourth edition considers all innovation, besides product innovation, to be forms of process innovation. Others in research and practice have presented other options which include: business model innovation (Foss & Saebi, 2017; Zott et al., 2011), marketing innovation (Gupta & Malhotra, 2013; Michel, 2014; Zhou et al., 2005), and innovation frameworks (Keeley, 2013; Moore, 2005).

The specific problem was that the A-U model, which guides innovators and researchers (Akiike, 2013; Teece, 1986), does not include the forms of non-technological innovation that are generally accepted by experts (OECD, 2018). These new forms of innovation have been shown to produce returns that are four times larger, and far more sustainable, than traditional product/process innovation (Lindgart et al., 2009).

In this qualitative e-Delphi study, an AHP decision model was used to help build consensus among a panel of expert innovators and researchers. Experts participating in this study were asked to agree to standard forms of innovation for the evaluation, confirm the market share leader at each stage of the lifecycle, and identify the form of innovation used by each to achieve leadership.

The Delphi method is a well-established qualitative tool that can help build consensus among a panel of experts (Linstone & Turoff, 1975). Donohoe et al. (2012) proposed an e-Delphi process, using electronic communication, to streamline

communication and make the process transparent for the expert participants. The AHP can be used to form a mathematical consensus when decisions are based both on fact and on judgement (Saaty, 2008). The combination of both e-Delphi & AHP techniques removed the subjectivity sometimes associated with the Delphi method (Hsu & Sandford, 2007) and allowed for faster convergence of the views of expert panel participants.

Alternatives Considered

Kotler (1965) outlined a quantitative model for representing market share that includes parameters for price, advertising, and distribution. He showed how this model could be modified to reflect different strategic approaches to marketing and the marketing mix. For example, in a market with two firms, Kotler modeled a strategy where each competitor mimics the advertising spend of the other. Weiss (1968), using another quantitative technique, examined the determinants of market share in the consumer products industry using price, advertising, distribution, and physical product characteristics as independent variables. Linear regression was used to evaluate the significance of these elements. Bell, Keeney, and Little (1975) also outlined a general mathematical theorem that can represent market share and various components that might factor into the calculation. This builds on the work of Kotler (1965) and others using general models for computer simulation.

Other quantitative research methods were also considered for this study. Murdick (1971) presents a collection of different mathematical methods that can be used to analyze marketing strategy, product planning, customer behavior, and sales. Buzzell and Wiersema (1981) explore a number of mathematical market share models, the most

popular being linear additive models or market share attraction models. The basic form of a linear additive model is:

$$MS_t = b_0 + b_1A_t + b_2A_{t-1} + \ldots + b_n B_{t-1} + b_{n+1}Bt + \ldots$$

where MS_t stands for market share in period t, and A, B, … are decision variables. MS_t is treated as a dependent variable which is determined by independent facts. These variables are used to capture the elements of the marketing mix such as price, advertising, distribution, competition. The use of quantitative methods is attractive because results are deterministic; however, in this case, it would require an understanding of the values for the independent variables, for the competitors in the market, for all 40 years of the study. Since some information, such as advertising and distribution spending, two variables highlighted by marketing luminaries like Kotler (1965, 1976), and Kotler and Armstrong (2017), are often not public information, this approach was not feasible for this project.

Several alternatives for qualitative methods were also explored. Case study analysis was considered for this research project. The case study technique can be a powerful qualitative research tool (Noor, 2008). This technique requires the researcher to gather data on a specific case, usually from multiple viewpoints or sources, and use that information inductively to build a more general conclusion (Eisenhardt, 1989; Patton & Applebaum, 2003; Yin, 2017).

In this study, market share leaders were identified for the entire 40-year lifecycle of the PC industry. This initial analytical step would be required using either a case study approach or another qualitative research design like Delphi. The case analysis technique would additionally require the collection and analysis of extensive public and private

information to determine the form of innovation used to establish market share leadership for each market leader identified (Yin, 2017).

The earliest observations occurred well before electronic access and archival was common. The data set starts in 1975, a timeframe that pre-dates the rise of the personal computer, the Internet, and distributed databases (Berners-Lee, 1992; Fluckiger, 1996; Yoffie & Kwak, 2001). This would make detailed research on the earliest market share leaders much more difficult and the information available incomplete. The result of this approach, even if time permitted, would still be a subjective judgement of the research materials rather than the collective judgement of a panel of experts who have specific insights into the dynamics of the industry over time.

Input bias based on the specific inputs selected, or available, is a weakness of the case technique (Eisenhardt, 1989; Patton & Applebaum, 2003). Given the size of the data set, and the amount of information available, the case study technique was judged to be too time-intensive for the timeline of this project. Grounded theory was also considered too time intensive for this study based on a number of the same data gathering and data availability concerns.

Narrative, phenomenological, and ethnographic qualitative research designs were also considered for this study. These designs focus on the individuals and the experiences associated with an outcome (Creswell & Creswell, 2017). In this case, the focus of the research is the linkage between the observed macro-economic outcome of market leadership and the form of innovation that enabled leadership. This analysis takes place first at the market level, and then at the firm level, but does not explore the personal

characteristics of any of the individual actors involved in process. In a future research project, if the focus shifts to exploring personal behaviors or attitudes that could have influenced this outcome, these designs may be a better fit.

Mixed method research designs combine qualitative and quantitative research techniques (Creswell & Creswell, Ibid.). Several quantitative mathematical models were explored earlier; however, they were not selected because of the amount and availability of data. With the exception of Delphi, qualitative methods were rejected because our analysis takes place only at the market and firm level. These same limitations will also impact any mixed method design based on synthesizing these techniques.

Using the collective wisdom of a team of experts is a specific advantage of the Delphi method (Dalkey, Ibid.; Linstone & Turoff, Ibid.). Delphi is well-suited for improving the understanding of problems, opportunities, and solutions, or to develop forecasts, especially in cases where mathematical models or other well-accepted research designs are not feasible (Linstone & Turoff, Ibid.; Skulmoski, Hartman, & Krahn, 2007). Based on the data currently available, the volume of data under consideration, and the timeline for this project, a Delphi research design, using an AHP decision model, appears to be the most effective and realistic approach to this research problem.

Role of the Researcher

The role of the researcher in this study is to (a) research the critical elements that influence the topic, (b) design the study, (c) research market share data, (d) develop (e-Delphi) research tools, (e) recruit the participants, and (f) capture the results, and (g) analyze the results and draw conclusions as it relates to the research topic. The market

share information is taken from publicly available sources that can be verified by participants, readers, and researchers. The research goal was to recruit no less than 20 panel members who are experts in the PC industry and have insights into the evolution of the industry. Purposeful selection was used to select panel members based on industry expertise. Selection was based on the response to a LinkedIn invitation and subsequent review of respondents' public profile. The acceptance of participants was not based on a personal relationship with the me or any specific organizational affiliation(s). Participants may have been university colleagues or professional acquaintances; however, participants did not include students or anyone with a reporting relationship to me. Participants did not receive cash or other compensation for their assistance; but they will receive access to the core data, research results, and conclusions.

Methodology

This qualitative e-Delphi study, using an AHP decision model, used the collective wisdom of a panel of experts to establish a consensus on the sources of innovation used by market share leaders in a technology industry, to assist innovators in the future.

Delphi Research Method

The Delphi method was developed in the 1950s at RAND corporation by Helmer, Dalkey, Gordon, and associates, where it was used to forecast the influence of technology on conflict and warfare for the U.S. Air Force (Dalkey & Helmer, 1963; Linstone & Turoff, 2011). The underlying concept was to leverage the intuition and judgment of experts, especially in cases where formal mathematical models or well-accepted problem solving techniques do not exist (Linstone & Turoff, 1975).

The Delphi method has evolved significantly from a forecasting methodology (Dalkey, 1968), into a technique that facilitates discussion for a wide range of problem solving situations (Linstone & Turoff, 2011). Kobus and Westner (2016), based on the work of Paré, Cameron, Poba-Nzaou, and Templier (2013), distinguish four types of Delphi studies: (a) Classical Delphi focusing on facts to create a consensus, (b) Decision Delphi focusing on preparation and decision for future directions, (c) Policy Delphi focusing on ideas to define and differentiate views, and (d) Ranking-type Delphi focusing on identification and ranking of key factors, items, or other types of issues.

This technique has been used to build consensus on the definition of successful diversity initiatives (Heitner, Kahn, & Sherman, 2013), explore issues related to information systems (Kobus & Westner, 2016; Skinner et al., 2015; Skulmoski et al., 2007), select international procurement strategies (Ojo & Gbadebo, 2012), determine the critical success factors for Quality Engineering in international automotive companies (Tri Putri, Mohd. Yusof, & Irianto, 2014), and many others (Adler & Ziglio, 1996; Clayton, 1997; Paraskevas & Saunders, 2012; Yousuf, 2007). In their original book, Linstone and Turoff (2011) had a bibliography with over 670 Delphi-related items; the number of citations for this publication on Google Scholar has now grown from 2,200 in 2010 (Linstone & Turoff, 2011), to over 9,400 in 2019 (Google Scholar, 2019a).

A traditional Delphi process typically consists of three to five rounds; though the ultimate goal of the Delphi technique is to reach consensus among the participants, and any number of rounds may be used (Delbecq, Van de Ven, & Gustafson, 1975; Hsu & Sandford, 2007). In the first-round participants typically respond to an exploratory

questionnaire. In the second-round responses are consolidated by investigators and participants are asked for their position on the consolidated statements. A similar process of consolidation and revision continues for the third and as many subsequent rounds as required. The right number of rounds should ultimately be determined by the complexity of the subject matter and the degree of consensus required by investigators (Linstone & Turoff, 1975). This study did not exceed three rounds based on the use of AHP to arrive at a mathematical consensus.

Analytical Hierarchical Process (AHP)

Saaty (1980, 1995, 2008) and Golden et al. (1989) have shown that when choices are ranked based both on fact and individual judgment, the AHP decision model is an effective tool to accomplish this task. This methodology uses pairwise comparisons to allow experts to establish weights for different pairs of choices. This process has been applied in a wide number of applications and industries (Lee et al., 2007; Phan & Daim, 2011; Zehr et al., 2014). Ishizaka and Labib (2011), Russo and Camanho (2015), and Emrouznejad and Marra (2017), have all provided comprehensive reviews of applications, issues, and recent evolution of the AHP technique.

Participant Selection Logic

The research goal was to recruit no less than 20 panel members, consistent with Ludwig (1997) and Hsu and Sandford (2007), who are experts in the technology industry and have insights into the evolution of the industry. Purposeful selection was used to select panel members based on industry expertise. Selection was based on the response to an electronic invitation sent to my network of LinkedIn connections. My personal

network on LinkedIn has 2,613 first level connections and a second-level reach of over 1.4 million contacts (LinkedIn, 2019). This LinkedIn account has been active for over 15 years. Over the last 15 years I've worked in business consulting, technology, telecom, sports equipment/apparel, mortgage marketing, direct mail advertising, and education. I've taught at Eastern Oregon University, Oregon State University, Portland State University, Concordia University, Marylhurst University, and Northeastern University. A number of my connections are also long-time business associates and colleagues that I've met over the course of my career. Over that period of time, I've established and managed more than 25 strategic and affiliate relationships with organizations such as: Microsoft, US Postal Service, United Parcel Service, Office Depot, Xerox, Kinko's (FedEx), IKON, Experian, InfoUSA, Pitney Bowes, GMAC Real Estate, Prudential Real Estate, First American Real Estate, Home Savings of America, American Electronics Association, and others. In short, this is an extremely diverse network of professionals from a wide range of industries and geographies, that has been established over time.

Participants all had at least 20 years' experience in the technology industry and a firm understanding of the technologies involved and how the industry took shape. The LinkedIn profile of potential panel members was examined to verify that participants met the minimum requirements. Participants also agreed to respond to electronic e-Delphi requests within two weeks for each round of questions. Panel members received an electronic reminder if a response was not received in a timely manner. The screen shots for the introduction and the survey are included in Appendix A. These (draft) screens

were implemented using Survey Monkey for this research project. The actual screens implemented in Survey Monkey are shown in Appendix B.

Instrumentation

The market share information is taken from publicly available sources that can be verified by participants, readers, and researchers. Participants received an invitation and screening message through LinkedIn. Communication with participants for this study was conducted online. Participants responded to questions using Survey Monkey web pages.

Once the study began, participants received a welcome message, along with a first-round online questionnaire that gave them the opportunity to review and validate market share numbers and the forms of innovation that were used for this research project. This study started with the forms of innovation outlined in the third edition of the Oslo manual (OECD, 2005). However, participants were also allowed to suggest other categories beyond those outlined in the OECD (2005) guidelines.

Once the panel reached consensus on the forms of innovation, panel members then received a second round online questionnaire which asked them to select the form of innovation used by each market share leader. Based on these results, a mathematical consensus was calculated using the pairwise comparison technique of AHP. The consensus results were shared with participants and they had the opportunity to provide

feedback (positive/negative) on the results. The screen shots for the questionnaires implemented in Survey Monkey are included in Appendix B.

Procedures for Recruitment, Participation, and Data Collection

The nature of this study was a qualitative e-Delphi process with an analytical hierarchical process (AHP) decision model process based on 40 years of historical industry results. An expert panel was used to analyze the form(s) of innovation used to establish market share leadership by industry competitors at each stage in the lifecycle of the PC industry (1975 to 2019). This analysis was performed in five steps.

First, the market share results for the study period were collected and analyzed to identify the market leaders for each stage over the historical lifecycle. A pilot test of 3 to 4 participants was conducted to assure that the questions and instructions were clear and easy to follow. Unit sales market share numbers for the market leaders in the PC industry were compiled in this step. The time-frame for this analysis was the 44 year period from 1975 to 2019. The data was based on research results published by International Data Corporation (IDC), Gartner Group, and Ars Technica (Reimer, 2005).

The top five market share leaders in each year of the historical observation period were identified for every year. This study did not include all possible competitors in the market. There were more than 250 competitors at some points in time and most of them had an insignificant market share (Steffens, 1994). Since the focus of the study is market share leadership driven by different forms of innovation, it was consistent to include only market leaders for each year of the analysis.

Second, the market share leaders identified were mapped to specific stages in the historical product lifecycle using the diffusion theory of Rogers. The stage of the lifecycle was determined by creating a technology adoption curve as outlined by Rogers (2003), Utterback and Abernathy (1975), and Utterback (1994). The starting date for the industry, 1975, has been established by Reimer (2005). The entry by IBM into the market in 1982 established a dominant design (Steffens, 1994). The model outlined by Rogers (2003) also states that adoption should follow a normal curve. The U.S. Census has included a question in periodic surveys about computer ownership in the household as far back as 1984 (U.S. Census Bureau, 2014). There are similar observations available from 1984 through 2016 that helped guide creation of the specific diffusion curve for the industry (U.S. Census Bureau, 2018).

Third, expert panel participants were asked to validate market share leaders and the forms of innovation that were used for the study. The initial choices offered were consistent with the third edition of the Oslo manual and included product, process, marketing, and organizational innovation (OECD, 2005). Panel members were also allowed to offer suggestions on other forms of innovation at this stage. The primary goal of this stage was to reach a consensus among panel members on market share leaders and the forms of innovation that were used in the evaluation.

Fourth, Likert scale questions were used by panel members to select the form of innovation used by each market share leader at each life-cycle stage. These results were converted to pairwise comparisons using the technique of Kallas (2011). The results were then aggregated using a geometric mean (Forman & Peniwati, 1997) to establish a

mathematical consensus on the form of innovation underlying market leadership at each stage of the product lifecycle. The consistency of the results for each market share leader was also validated by calculating the AHP consistency index for each. If the results were found to be inconsistent, then inconsistencies would have been analyzed, and participants with inconsistent results will be contacted for clarification.

Data Analysis Plan

The process started by compiling a list of U.S. PC market share leaders from 1975 – 2019. The data was based on research results published by International Data Corporation (IDC), Gartner Group, and Ars Technica (Reimer, 2005). In cases where the information was not complete, or there were gaps, additional estimates were overlaid based on equally reputable publicly available sources. In some cases, where there were individual observations missing, and the overall trajectory of the data might be affected, the data was normalized and smoothed to assure a complete data set.

In order to map market share leaders to stages in the lifecycle, information from the U.S. Census Bureau was used to align specific market penetration rates to the normal curve for market adoption proposed by Rogers (2003). The U.S. Census has included a question in periodic surveys about computer ownership in the home as early as 1984 (U.S. Census Bureau, 2014). There are similar observations available for 1984, 1989, 1993, 1997, 2000, 2001, 2003, 2007, 2009, 2010, 2011, 2012, 2014, 2015, and 2016 (U.S. Census Bureau, 2018). This information provided a market adoption curve for the home PC segment of the industry. The U.S. Department of Labor conducted surveys in 1984, 1989, 1993, 1997, 2001, and 2003 to estimate the numbers of workers who used a

PC at work (Bureau of Labor Statistics, 2005; Friedberg, 2003; Hipple & Kosanovich, 2003). This information was also used to examine the diffusion curve for the business segment of the PC market.

The e-Delphi study was conducted using a set of two surveys implemented in Survey Monkey. The draft screens are outlined in Appendix A, the final screens are shown in Appendix B. The first page of the first survey was the informed consent that was approved by the Institutional Research Board (IRB: 12-20-19-0741551). In the following screens, the research project was described for expert panel participants, and they were asked to confirm the market share data set and the forms on innovation outlined in the third edition of the Oslo Manual (OECD, 2005). The individual responses to these questions and the comments were reviewed. If there had not been a convergence of responses, then the data set and/or forms of innovation would have been revised, and the process would have been repeated until convergences was reached.

Once agreement on the data set and forms of innovation was reached, expert panel participants were asked to rank the importance of each of the approved forms of innovation when establishing market leadership for each market share leader. Expert panel participants were also asked for their confidence level for each response and to identify any potential changes in focus over the time of market leadership.

The confidence level responses were analyzed using numerical analysis to indicate if there were changes in confidence for specific market share leaders. The individual forms of innovation responses for each market share leader were captured as a Likert value using a scale of 1 – 9. The responses were then aggregated using a geometric

mean, and then the aggregated results, were converted to pairwise preferences using the technique outlined by Kallas (2011). Once the transformation was performed, then the pairwise comparison technique Saaty (1980, 1995, 2008) was applied to the results for each market share leader to produce a priority vector and a consistency ratio. If the consistency ratio had been greater than .1, the data would have been explored further for consistency issues. The priority vectors were analyzed to establish the importance of each form of innovation, for each market share leader, and then mapped to the appropriate stage in the lifecyle to identify innovation trends over time.

Issues of Trustworthiness

Credibility

The initial analysis in Step 1 was based on publicly available information provided by Gartner Group, International Data Corporation (IDC), and Ars Technica (Reimer, 2005). These organizations are generally regarded as highly reliable in the research and media industries. Gartner Group, started in 1979, is one of the largest technology research and advisory firms in the world with over 6,600 associates, 1,500 analysts, and clients in over 85 countries (Gartner Group, n.d.). Gartner is traded on the New York Stock Exchange under the symbol IT and was selected as one of the most admired corporations in the world for Information Technology Services by Fortune magazine in 2018 (Fortune, 2019). International Data Corporation (IDC), created in 1964, a subsidiary of International Data Group (IDG), is a leading source of technology research for IT professionals, business executives, and the investment community (IDC, 2019). IDC has more than 1,100 analysts worldwide and offers research products in over

110 countries. Ars Technica is a subsidiary of Condé Nast, a global news and media company, that monthly reaches 84 million consumers in print, 367 million in digital, and 379 million across social platforms (Condé Nast, 2019). The market share data was also validated by an expert panel with extensive and verified industry experience.

The diffusion of innovation model used in Step 2 is based on the work of Rogers (1962, 1976, 2003) and Rogers and Shoemaker (1971), which has become widely established in the marketing literature (Wright & Charlett, 1995). The book, *Diffusion of Innovations*, is now in its fifth edition, with the distribution of each edition reaching more than 30,000 (Goodreads, 2019). The number of citations for this work on Google Scholar currently exceeds 106,670 (Google Scholar, 2019b).

The Delphi method is based on a systematic consensus building exercise using a panel of experts and a facilitator. The use of experts helps establish credibility for this type of research design (Hallowell & Gambatese, 2009). The e-Delphi process also makes it possible to collect results more quickly and eliminate undue influence of others since participants in this research design were inherently anonymous (Donohoe et al., 2012). In their original book on the Delphi technique, Linstone and Turoff (1975), had a bibliography with over 670 Delphi-related items; the number of citations for this publication on Google Scholar has grown from 2,200 in 2010 (Linstone & Turoff, 2011), to over 9,400 in 2019 (Google Scholar, 2019a). The consensus on the form of innovation used by each market leader in this qualitative e-Delphi study included a panel of experts with extensive and verified industry experience.

An AHP pairwise decision model was used to remove subjectivity from the consensus building process. Saaty (1980) originally developed AHP in the 1970s as a way of addressing weapons tradeoffs, resource and asset allocation, and decision making, when working with the State Department's Arms Control and Disarmament Agency, and as a Professor at the Wharton School of Business (Alexander, 2012). A recent social network analysis of the period between 1979 and 2017 conducted by Emrouznejad and Marra (2017), showed 8,441 published works on AHP: including 4,721 papers, 3,362 conference proceedings, 211 articles and proceedings papers, and almost 150 other documents. The number of publications has steadily increased since 2017, with the record years being 2013 and 2015, with more than 800 works per year published. The ground-breaking book on AHP by Saaty (1980), *How to make a decision: The Analytical Hierarchy Process*, has now reached 56,688 citations on Google Scholar (Google Scholar, 2019c).

The forms of innovation chosen as a starting point for this analysis come from OECD, an international organization, representing 36 democracies with market-based economies, and more than 70 non-member countries, which performs research and advocates for policies that encourage innovation and sustainable economic development (OECD, 2019). OECD member countries are responsible for 63% of world GDP, 75% of world trade, and 95% of official world development assistance (U.S. Mission to the OECD, n.d.). OECD has been publishing the Oslo manual, and providing guidance on measuring innovation, for almost 3 decades (OECD, 2018) and continues to refine it based on input from member countries.

Transferability

This research structure should be straight-forward to duplicate for any industry in which market share data exist and an expert panel can be recruited. The research design is not specific to the industry under study or the time-frame studied. The tools used to conduct this research are all publicly available for low/no charge. The web pages for the panel questions can be easily replicated using Survey Monkey. The Delphi questions and layout are all captured in Appendix B of this research study. The process has been clearly documented so that it can be replicated for other industries or products.

Dependability

Market share information was gathered from reputable publicly reported sources. The data set is reproduced in Appendix D and shared electronically through the ProQuest database. OECD publishes the Oslo manual online, references for each version are captured in this research study, and all four versions are posted on their website and can be downloaded for free. The industry experience of each participant was verified using their LinkedIn profile before the study began. The names of expert panel participants were not shared with other participants in the study to assure anonymity. This study is based on 40 years of industry data, and the Delphi results come from the collective wisdom of verified technology experts, to assure dependability.

Confirmability

The information and process used in this study will be publicly available for any researcher to duplicate and confirm the results. Market share information is available

from the publicly reported sources outlined here, which will be published with this research study. The questions and web pages will also be available for any researcher.

Ethical Procedures

There were no ethical issues encountered in this type of analysis. The raw data used is all publicly available. There is no confidential or proprietary data involved. Participants volunteer for the panel and are not paid to participate, although participants will receive a copy of the findings. Panel experts do not have a reporting relationship or a student/teacher relationship with me. The experience of panelists was verified using their public LinkedIn profile. Participant names are not shared with other participants or with anyone outside the study. The data gathered is captured in tables and appendices that are included with the study and published along with the research results. Backup copies will be saved by the researcher and the study will be published on ProQuest by Walden university. Any archived data collected in this study, that is not included in the published research report, will be destroyed after 5 years. This final step is required by Walden university data privacy policy.

Summary

The purpose of this qualitative e-Delphi research project was to build consensus with an expert panel of innovators and researchers on the forms of innovation used to establish market leadership over the historical lifecycle of a technology industry. Now that agreement has been established, if the results are proven to be conclusive, they may be added to the A-U model (Utterback & Abernathy, 1975), to create a baseline for non-technological innovation within that framework and serve as a guide to future innovators.

The methodology used was an e-Delphi research design using an AHP decision model. Unit sales data on the PC industry was collected from public sources for the historical period from 1975 to 2019. This data was analyzed to determine the market share leaders over that period and Rogers diffusion model was used to map the market share leaders to specific points on the diffusion curve. Census data was used to estimate the diffusion curve for the consumer market segment of the U.S. PC market. Information from the U.S. Department of Labor was used to approximate the diffusion curve for the business user market segment.

The e-Delphi panel participants were recruited using an electronic invitation sent to them using LinkedIn. Panel participants all have at least 20 years' experience with the PC industry and a general understanding of the technology involved and the evolution of the industry. The experience of panel members was verified using their public LinkedIn profile. Panel participants do not have a reporting or student/teacher relationship with me and committed to responding within two weeks to each instrument.

Since this project is based on publicly available information using a panel of experts, peer review and credibility are built right into the project. The process used in this project should be straight-forward to transfer to other industries and products. This project was based on public information evaluated by a panel of experts assuring dependability and confirmability. There were no ethical issues encountered based on the design and data collection techniques being used. The research results are analyzed in Chapter 4. Discussion, conclusions, and recommendation are the focus of Chapter 5.

Chapter 4: Results

The general problem was that there is no consensus on the forms that non-technological innovation can take. The forms of innovation in the second edition of the Oslo manual (OECD, 1997), the third edition (OECD, 2005), and the fourth edition (OECD, 2018), are not consistent. The second version aligns with the traditional A-U model, the third extends beyond the A-U model by including marketing and organizational innovation, the fourth version considers all innovation, besides product innovation, to be forms of process innovation. Others in research and practice have presented other options which include: (a) business model innovation (Foss & Saebi, 2017; Zott et al., 2011), (b) marketing innovation (Gupta & Malhotra, 2013; Michel, 2014; Zhou et al., 2005), and (c) innovation frameworks (Keeley, 2013; Moore, 2005).

The specific problem was that the A-U model, which guides innovators and researchers (Akiike, 2013; Teece, 1986), does not include the forms of non-technological innovation that are generally accepted by experts (OECD, 2018). These new forms of innovation have been shown to produce returns that are four times larger, and far more sustainable, than traditional product/process innovation (Lindgart et al., 2009).

The goal of this research study was to use historical market share data for the period from 1975 – 2019, combined with expert opinion on the forms of innovation used by each market share leader, to answer the following research question:

"What is the consensus of an expert panel of innovators and researchers on the form(s) of innovation that were used by competitors to establish market leadership over the historical lifecycle of a technology industry?"

In this chapter, the research and data collection process used in this study is discussed. The chapter begins with an overview of the pilot study and research setting. Demographics and data collection are then described in more detail. The process of recruiting participants and collecting data is outlined. The results of the e-Delphi survey research and the detailed analysis are also presented.

Pilot Study

The pilot study was conducted by me and two colleagues at Eastern Oregon University. Since this was an online e-Delphi process, and the survey was developed and administered using Survey Monkey, the goal was to assure that all the screens and response fields accepted input and were easy to follow. In Phase 2, I chose to add graphics that illustrated market share to make it easier for participants to visualize. The decision was also made to track the IP address of each respondent so that we could tie Phase I results directly to Phase 2 results, if required. An email invitation was also developed to augment the LinkedIn social media post that was developed earlier. Once the surveys for both Phases were validated, and the pilot study was complete, the database was cleared of existing pilot study responses and opened for new participants.

Research Setting

This was an e-Delphi study that was conducted online. I did not have any insight into the research setting for individual participants. The was no specific requirement that participants take the survey from work or home. The only requirement was that participants have an Internet connection and access to a browser-based input device. Some e-Delphi participants reported that there were too many companies to rank and it

got a little taxing towards the end. Consistent with traditional Delphi studies, we showed some participants dropped out along the way. Thirty participants started the Phase 1 survey and 27 completed it. Twenty four participants started the Phase 2 survey, 23 participants ranked at least four of the market share leaders, and 19 participants completed the entire survey. These numbers are consistent with our goal for the study or 20 expert panel participants. The participation rates are outlined in Figure 6.

Phase 1	
question 1	30
question 2	27
Phase 2	
Altair	24
AST/Tandy	23
Apple 1	23
IBM	23
Commodore	19
Apple 2	20
Packard Bell	18
Compaq	19
Dell	19
HP	19
Lenovo	19

Figure 6. e-Delphi expert panel participation rates by survey phase and question posed.

Demographics

Purposeful selection was used to invite expert panel members from my LinkedIn network. My personal network on LinkedIn has 2,613 first level connections and a second-level reach of over 1.4 million contacts (LinkedIn, 2019). This is an extremely diverse network established over a long period of time. Prospects were invited based on

having more than 25 years' experience in technology or research. Participants were selected based on a review of their LinkedIn profile. There were no other demographic restrictions or limitations on participants.

Data Collection

PC Market Share Leaders 1975 - 2019

This research study used U.S. market share sales numbers for the personal computer (PC) industry over the period from 1975 – 2019. The numbers were compiled using an overlay of several different data sets described in this study. The numbers were normalized in cases were gaps exist.

The process started by collecting the market share of the vendors in U.S. PC market from 1980 – 1994 as published in *Computer Industry Forecasts and Newgames: Strategic Competition in the PC Revolution* (Steffens, 1994). These numbers were confirmed and extended to 1998 using International Data Corporation (IDC) estimates (Narayandas & Rangan, 1996; Rivken, Porter, & Nabavi, 1999).

Information on the earliest years of the PC industry came from *Total share: 30 years of personal computer market share figures* (Reimer, 2005). This data set contains detailed information on early industry pioneers such as Altair, Atari, Commodore, and Apple. IBM and IBM compatible systems are combined in this data set, but not in the Steffens (1994) data set. The first IBM PC was not launched until 1982, so the Reimer data from 1975 – 1981, was combined with Steffens 1980 – 1994 data, to establish market share numbers from 1975 – 1998. The data for Atari and Commodore in the

Reimer data, were normalized using the total units shipped numbers reported, to extend the market share number for Atari and Commodore out to 1998.

The market share numbers for U.S. PC vendors 1994 – 2008 were provided by International Data Corporation (Rivken, 2010). U.S. PC market share numbers for 2009 – 2015 were published by IDC (International Data Corporation, 2016). The U.S. PC market share numbers for from 2013 – 2019 were calculated by Gartner Group (2020a) and cross-checked with IDC numbers. Worldwide market share numbers, used to determine Lenovo was the top PC vendor worldwide 2013 – 2019, came from Gartner Group (Gartner Group, 2020b).

Only the market share leaders were reported for each time period. The numbers for all vendors were not included because in some time periods there were more than 250 vendors (Steffens, 1994) and we are only concerned with market leadership in this study. The penetration rates for PCs in U.S. homes are published by the U.S. Census Bureau. The U.S. Census has included a question in periodic surveys about computer ownership in the home as early as 1984 (U.S. Census Bureau, 2014). There are similar observations available for 1984, 1989, 1993, 1997, 2000, 2001, 2003, 2007, 2009, 2010, 2011, 2012, 2014, 2015, and 2016 (U.S. Census Bureau, 2018). The U.S. Department of Labor conducted surveys in 1984, 1989, 1993, 1997, 2001, and 2003 to estimate the numbers of workers who used a PC at work (Bureau of Labor Statistics, 2005; Friedberg, 2003; Hipple & Kosanovich, 2003).

e-Delphi Research Study – Phase 1

The e-Delphi study was broken into two pieces: Phase 1 and Phase 2. The process that was used is outlined in Figure 7.

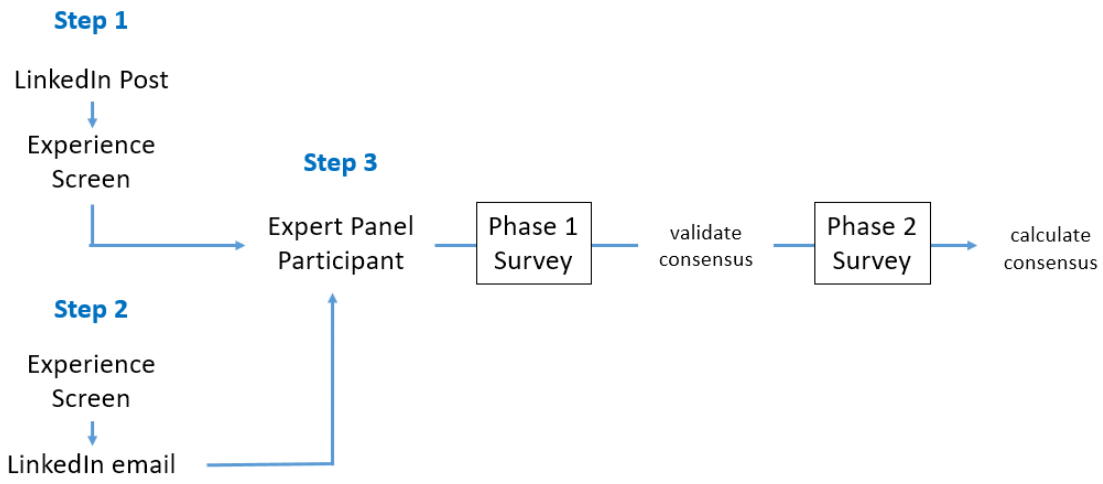


Figure 7. Flow-chart of e-Delphi process used to recruit the expert panel in this study.

The research goal was to have at least 20 technology experts participate in the study. In Phase 1 the research project was described, and panel members were asked to validate the leadership numbers for the PC industry and the forms of innovation published by the OECD. The informed consent, which was approved by Walden's IRB (IRB: 12-20-19-0741551), was included as the first screen in the Phase 1 survey. The informed consent and Phase 1 screens implemented in Survey Monkey are included in Appendix B.

The recruiting process was started by submitting a post to my personal network on LinkedIn. The responses were screened to assure each prospective participant had

more than 20 years of experience in the technology industry. There were five responses that met these criteria. The network was then pro-actively scanned for connections with more than 20 years of experience in the technology industry. These prospective panel participants were sent a personal invitation to participate along with an URL which connected to the Phase 1 study.

This was a blind expert panel research project as required by IRB. Panel members, once screened, did not provide an email address or other identifying information. The IP address of respondents was captured only to tie respondents from Phase 1 to the Phase 2 survey information. 30 experts participated in Phase 1 of the research project.

The results of Phase 1 were evaluated to assure expert panel convergence. The industry leaders were validated by 24 (80%) of the participants. The other 6 experts (20%) provided comments that expressed minor concerns. The numbers presented to participants were re-confirmed to assure accuracy based on publicly available information.

The forms of innovation presented were confirmed by 26 (94%) of expert panel participants. The only (1) panel participant that expressed concern felt that the model was overly simple, and that pricing should play a larger role in the analysis. The purpose of this research study is to investigate innovations that enable market leadership. Innovations, such as process innovation, that produce greater economies of scale, and result in lower market prices, are covered under the OECD definitions. This research project is focused on those innovations that enable market leadership.

e-Delphi Research Study – Phase 2

In Phase 2, participants were asked to rank the importance of the forms of innovation used by each market share leader to establish market share leadership. There were 10 US market share leaders presented which covers the period from 1975 – 2019. The current worldwide market share leader, Lenovo, was also included in the analysis. Twenty five experts participated in Phase 2 of the research project.

An AHP decision model was used to establish a mathematical consensus, which required only one round of responses from the expert panel. The Phase 2 screens implemented in Survey Monkey are included in Appendix B. The complete results for each market share leader are presented in Appendix C.

Data Analysis

Survey participants were directed to rank the importance of each form of innovation for establishing market share leadership for each U.S. market share leader in the PC industry over the period from 1975 – 2019. This required participants to rank the form of innovation for 10 separate U.S. market share leaders. In addition, Lenovo was added to the data set because they have been the worldwide leader since 2013, and with their current momentum, they could soon be the U.S. market share leader as well.

Some in the psychological community assert it is easier and more accurate to express opinions on only two alternatives rather than simultaneously on all alternatives (Ishizaka & Labib, 2011). That general belief has given rise to the use of the pairwise comparison in AHP. In this case, participants were asked to rate the form of innovation for each market share leader using a Likert scale ranging from (1) not important to (9)

very important. The scale of 1 to 9 was chosen to mirror the typical pairwise comparison scale suggested by Saaty (1980). The challenge with only using a traditional pairwise comparison approach alone in this scenario is three-fold.

First, the number of individual comparisons required with pairwise comparison can be large. The formula used to calculate the number of comparisons is N(N-1)/2. With eleven different companies to rank, and four different forms of innovation, that represents 66 separate comparisons. Using the Likert technique, only 44 rankings are required, and each element can be ranked on its own merits, without regard to the importance of the other collection of factors.

Second, when ranking a large number of pairwise comparisons the consistency of judgements can become an issue. Consistency requires that in an ordered list of a, b, and c, if a is preferred to b, and b is preferred to c, then a must also be preferred to c. When selecting the relative importance of two variables at a time, when the rest of the universe of choices is not visible, inconsistency can occur in the individual judgements. Saaty (1980) proposed a consistency ratio to determine the level of consistency. However, when using a Likert scale to compare the importance of individual forms of innovation, consistency should not be an issue, because each element is being judged independently. Consistency indexes were calculated for each market share leader just for the sake of validation and completeness.

Finally, pairwise comparison requires judging the relative importance between two decision elements. This type of decision making breaks down when there are two elements that are of equal importance or where neither one is important. In the former

case, if two elements are judged to be of equal importance, does that mean that they are equally very important, equally unimportant, or equally somewhere in between? In the case where elements are equally unimportant, using the pairwise comparison technique, it is not possible to indicate one element is completely unimportant, all that is determined is the relative importance in relationship to other elements.

One solution to this problem is to use a Likert scale for each form of innovation and then transform these individual rankings into comparisons using the technique of Kallas (2011). The transformation takes the form of $a_{ij} = |judgement_{ik} – judgement_{jk}| + 1$ for every element of the i x j AHP decision matrix and every decision maker k (Kallas, 2011). The 1 is added to assure that the resulting value is greater than zero (entries in the AHP decision matrix must positive and non-zero). One challenge with this approach is that the sign (+/-) of the transformation indicate whether the value belongs in the positive or reciprocal portion of the matrix. This requires calculating the geometric mean of the sum of the judgements for each expert, performing the transformation as above, and preserving the signs first. Then further transforming the result by taking the absolute value and adding 1. This step is omitted in the technique presented by Kallas (2011).

$$\begin{array}{c} \\ a_1 \\ a_2 \\ a_3 \\ a_4 \end{array} \begin{array}{c} \begin{array}{cccc} a_1 & a_2 & a_3 & a_4 \end{array} \\ \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \end{array} \tag{1}$$

$$\begin{array}{c} \\ a_1 \\ a_2 \\ a_3 \\ a_4 \end{array} \begin{array}{c} \begin{array}{cccc} a_1 & a_2 & a_3 & a_4 \end{array} \\ \begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} \\ 1/a_{12} & 1 & a_{23} & a_{24} \\ 1/a_{13} & 1/a_{23} & 1 & a_{34} \\ 1/a_{14} & 1/a_{24} & 1/a_{34} & 1 \end{bmatrix} \end{array} \tag{2}$$

$$X_{ij} = \frac{a_{ij}}{\sum_{i=1..n} a_{ij}} \begin{bmatrix} X_{11} & X_{12} & X_{13} & X_{14} \\ X_{21} & X_{22} & X_{23} & X_{24} \\ X_{31} & X_{32} & X_{33} & X_{34} \\ X_{41} & X_{42} & X_{43} & X_{44} \end{bmatrix} \quad W_j = \frac{\sum_{j=1..n} X_{ij}}{n} \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ W_4 \end{bmatrix} \tag{3}$$

Figure 8. Matrix equations to transform pairwise comparisons into weight vectors. Derived in part from "The analytic hierarchy process: Planning, priority setting, resource allocation", T. Saaty, 1980, New York, NY, and "How to do AHP analysis in Excel", by K. Bunruamkaew, 2012, University of Tsukuba, Graduate School of Life and Environmental Sciences, Division of Spatial Information Science.

The AHP pairwise comparison technique can be described in more detail using the equations (1), (2), and (3) in Figure 8. The pairwise comparison matrix in (1) is composed of the comparison between elements a_i and aj or all *i* and *j*. In this case the variable in a_1 through a_4 represent the preferences for the forms of innovation being analyzed: product innovation, process innovation, marketing innovation, and organizational innovation, respectively. To simplify this analysis, the reciprocal properties of the matrix are used as shown in (2). On the vertical axis, when comparing a_{ij} to a_{ij}, the results is always 1. Since these are comparisons, the other relationship that

exists, is that if the preference between a_i and a_j is x, then the reciprocal relationship between a_j and a_i must be $1/x$ (Brunelli, 2015; Franek & Kresta, 2014).

In order to calculate the priority vector from the pairwise matrix in (2), a normalized matrix must be calculated as in (3), and the priority vectors are calculated using the average of the sum of each row in the normalized matrix. The resulting vector represents the priority for each element in the pairwise comparison (Bunruamkaew, 2012). Unlike the original Likert score, which exists as an interval scale (Boone & Boone, 2012), the priority matrix numbers are a ratio scale (Franek & Kresta, 2014), so the magnitudes can be compared to each other directly (Vargas, 2010). In other words, a priority value of .5, would be twice as important, and a priority value of .25.

$$Cv_{11} = \frac{1}{W_{11}}\left[a_{11}W_{11} + a_{12}W_{12} + a_{13}W_{13} + a_{14}W_{14}\right]$$

$$Cv_{12} = \frac{1}{W_{12}}\left[a_{21}W_{11} + a_{22}W_{12} + a_{23}W_{13} + a_{24}W_{14}\right] \qquad \lambda = \sum_{i=1..n} Cv_{ij} \qquad C_r = \frac{CI}{RI} \qquad (4)$$

$$Cv_{13} = \frac{1}{W_{13}}\left[a_{31}W_{11} + a_{32}W_{12} + a_{33}W_{13} + a_{34}W_{14}\right] \qquad CI = \frac{\lambda - n}{n - 1}$$

$$Cv_{14} = \frac{1}{W_{14}}\left[a_{41}W_{11} + a_{42}W_{12} + a_{43}W_{13} + a_{44}W_{14}\right]$$

n	1	2	3	4	5	7	9	10
RI	0	0	0.58	0.9	1.12	1.32	1.46	1.49

(5)

(Saaty, 1980)

Figure 9. Equations used to calculate Consistency Ratio's. Derived in part from "The analytic hierarchy process: Planning, priority setting, resource allocation", T. Saaty, 1980, New York, NY, and "How to do AHP analysis in Excel", by K. Bunruamkaew, 2012, University of Tsukuba, Graduate School of Life and Environmental Sciences, Division of Spatial Information Science.

Saaty (1980) proposed judging the consistency of the weights using a Consistency Ratio (CR). The CR can be calculated as the ratio between the Consistency Index (CI) outlined in (4) and the Random Index (RI) as shown in (5). The CI is the value of λ or the maximum eigen value, minus the number of elements divided by the number of the elements minus 1 (Al-Salamin & Elias, 2015; Rochman et al., 2018;). The value for λ is the average of the consistency weights calculated in equation (4). The weights are perfectly consistent when the CR = 0. In practice, a CR of zero is not common, and CR values that do not exceed .10 are considered acceptable (Bunruamkaew, 2012; Saaty, 1980; Vargas, 2010).

There are two primary techniques used to combine expert judgements in AHP. AIJ aggregates individual judgements; while AIP aggregates individual priorities (Russo & Camanho, 2015). In the first case, the average of the individual judgements is performed to create a single unified decision maker, and the AHP analysis is performed on this aggregated data. In the second case, AHP analysis is performed on the collection of individual judgements, and then those individual priorities are combined. Forman and Peniwati (1997) showed that when using the AIJ technique the geometric mean must be used to avoid violating the Pareto principle. In the case of AIP, either the arithmetic mean, or the geometric mean can be used. In this study, since the goal is to reach expert panel consensus, it is appropriate to use AIJ (Forman & Peniwati, 1997).

The complete process requires capturing the individual judgements from the expert panel. The geometric mean of each set of values is then calculated. These values are then transformed into pairwise comparison values using the technique of Kallas

(2011). Once this transformation has been made, the priority vector and consistency index can be calculated for each set of preferences, using the techniques described in this section and the equations in (1) – (5). The aggregate results of this transformation, along with the arithmetic and geometric mean of each data set can be seen in Figure 10.

Geometric Mean	Product	Process	Marketing	Organizational
Altair	7.60	3.15	3.90	2.25
AST/Tandy	6.78	4.45	5.99	2.68
Apple 1	8.26	4.50	6.91	3.76
IBM	6.15	5.53	6.15	5.29
Commodore	6.18	4.49	5.17	3.69
Apple 2	7.57	5.00	7.08	4.63
Packard Bell	4.62	5.56	5.14	4.21
Compaq	6.39	5.65	6.09	4.39
Dell	5.59	7.59	7.90	6.12
HP	5.21	5.02	5.55	5.50
Lenovo	5.56	5.37	6.47	4.85

AHP	Product	Process	Marketing	Organizational	CR
Altair	0.62	0.12	0.17	0.07	0.02
AST/Tandy	0.46	0.15	0.31	0.07	0.02
Apple 1	0.52	0.11	0.29	0.07	0.02
IBM	0.32	0.20	0.32	0.17	0.00
Commodore	0.45	0.17	0.26	0.11	0.01
Apple 2	0.44	0.12	0.34	0.10	0.01
Packard Bell	0.19	0.37	0.28	0.15	0.00
Compaq	0.37	0.22	0.30	0.11	0.00
Dell	0.11	0.33	0.40	0.15	0.00
HP	0.22	0.19	0.30	0.29	0.00
Lenovo	0.23	0.20	0.42	0.14	0.00

Figure 10. Geometric mean of individual judgements and priority vectors that were generated using the equations in Figure 8 and Figure 9.

Credibility

There were no major changes to the credibility strategy proposed in Chapter 3. The initial analysis in Step 1 is based on publicly available information provided by Gartner Group, International Data Corporation (IDC), and Ars Technica (Reimer, 2005).

These organizations are generally regarded as highly reliable in the research and media industries. The detailed process for compiling this data, and the original sources used, were outlined in this chapter.

The diffusion of innovation model used in Step 2 is based on the work of Rogers (1962, 1976, 2003) and Rogers and Shoemaker (1971), which has become widely established in the marketing literature (Wright & Charlett, 1995). The book, *Diffusion of Innovations*, is now in its fifth edition, with the distribution of each edition reaching more than 30,000 (Goodreads, 2019). The number of citations for this work on Google Scholar currently exceeds 106,670 (Google Scholar, 2019b).

The Delphi method is based on a systematic consensus building exercise using a panel of experts and a facilitator. The use of experts, each with 20+ years of experience, individually verified on LinkedIn, helps establish credibility for this type of research design (Hallowell & Gambatese, 2009). The e-Delphi process also makes it possible to collect results more quickly and eliminate undue influence of others since participants in this research design are inherently anonymous (Donohoe et al., 2012).

An AHP pairwise decision model was used to remove subjectivity from the consensus building process. Saaty (1980) originally developed AHP in the 1970s as a way of addressing decision making, when working with the State Department's Arms Control and Disarmament Agency (Alexander, 2012). The ground-breaking book on AHP by Saaty (1980), *How to Make a Decision: The Analytical Hierarchy Process*, has now reached 56,688 citations on Google Scholar (Google Scholar, 2019c).

The forms of innovation chosen as a starting point for this analysis came from OECD, an international organization, which performs research and advocates for policies that encourage innovation and sustainable economic development (OECD, 2019). Expert panel participants were asked to validate the forms of innovation in Phase 1 of the research study. The majority, 96% of participants, agreed that the definitions and categories of innovation appeared accurate.

Transferability

There were no significant changes required to assure transferability. The industry market share leader data set is based on publicly available information and the sources and composition process were covered earlier in this chapter. The process for recruiting participants and conducting the study are covered in this chapter. The survey screens have been captured in Appendix B. These screens were implemented using Survey Monkey, a publicly available tool. The AHP calculations are done using existing formulas in Excel and the spreadsheet will be downloadable for future researchers.

Dependability

Market share information was gathered from reputable publicly reported sources. The data set is captured in Appendix D and, once this dissertation is published, it will be shared electronically through the ProQuest database. OECD publishes the Oslo manual online, references for each version are captured in this research study, and all four versions are posted on their website and can be downloaded for free. The industry experience of each participant was verified using their LinkedIn profile to assure that

they had no less than 20 years' experience. The study was performed as a blind survey and the names of participants has not been shared or captured with survey results.

Confirmability

There were no significant changes required in this section. The information and process used in this study will be publicly available for any researcher to duplicate and confirm the results. Market share information is available from the publicly reported sources outlined earlier which will be published with this research study. The questions and web pages will also be available for any researcher.

Study Results

The results of the transformation process are shown in Figure 10. Unlike the aggregate Likert score numbers, which are an interval scale, the AHP priority vectors represent a ratio scale. That means that a value of .6 is twice as important as .3. When using AHP, a consistency ratio (CR) < .1 or below is considered acceptable. All of the results produced in this analysis fall within that range, which is to be expected because we used a Likert scale rather than a traditional pairwise comparison.

The research question for this study was: "What is the consensus of an expert panel of innovators and researchers on the forms of innovation that were used by competitors to establish market leadership over the historical lifecycle of a technology industry?"

Based on these results, in the opinion of our expert panel, Altair, Apple (1981-1982), and Commodore relied on technological innovation to secure market leadership. AST/Tandy, IBM, and Apple (1992 – 1993) combined technological innovation with

marketing innovation to lead the market. Starting with Apple in 1992, all of the market share leaders going forward, relied on some level of marketing innovation to establish market leadership. Compaq combined marketing with technological innovation. Packard Bell and Dell both used marketing with process innovation to minimize production costs. Only HP seems to demonstrate a significant use of organizational innovation to establish market leadership in the opinion of our expert panel. The results of the mathematical consensus produced can be seen in Figure 12.

One question that was posed in the research project concerned the A-U model. Using the A-U model it would be expected that competitors would focus on technological innovation early in the lifecycle, and then transition to process innovation as the market matures and the pressure on prices grows. This general pattern of behavior can be found in the results of this study. The early market leaders from 1975 – 1993 all relied on some level of technological innovation. Packard Bell (1994 – 1995) and Dell (2000 – 2008) both relied on process innovation. The one element that the A-U model did not predict is the importance of marketing innovation starting in 1992 and continuing even in 2019. The A-U model would also not predict the use of organizational innovation by HP. This makes sense because the A-U model does not include marketing or organizational innovation. The A-U model would seem to suggest a greater level of focus on process innovation later in the lifecyle then our experts suggest.

Rogers' (2003) model was used to bring additional clarity to the lifecycle stage of the PC market. The PC industry is broadly made up of home, business, educational, and government users (Rivken, 2010; Rivken, et al., 1999). The introduction of the IBM PC

in 1981 launched the PC market in earnest for business users. IBM still had a market share of 12% of household PC's in 1986. It is challenging to forecast the number of business PC users directly. The U.S. Census provides household penetration numbers starting as early as 1994 (U.S. Census, 2018). The U.S. Census also publishes the number of households by year. The combination of the two data sources can be used to create a lifecycle diagram for the household PC market. This analysis is summarized in Figure 11.

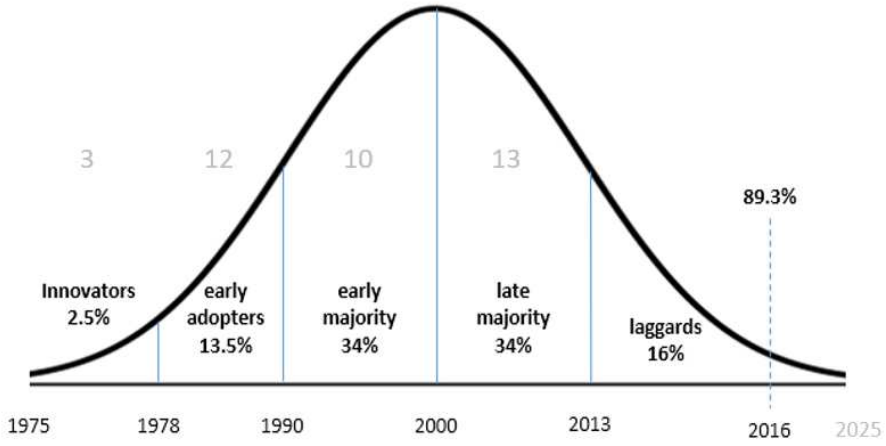
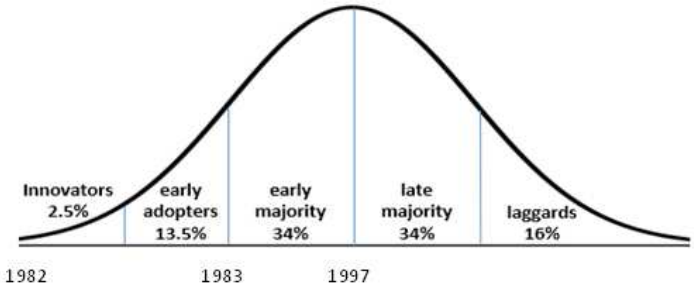


Figure 11. Diffusion curve derived for U.S. household PC adoption with the number of years required to reach each stage of diffusion.

In order to calculate the number of business, education, and government sales, the number of new homes adding a PC can be subtracted from the total sales of PCs in any given year. These numbers are available from IDC (Rivken, 2010; Rivken, et al., 1999) and could provide insight into the total volume of sales for each segment, but still would not provide direct insight into overall penetration rates. One additional complication is factoring in PC replacement cycles. Industry estimates put current replacement cycles in the range of 5 to 6 years (Daniel Research Group, 2019), an increase over the long-held

industry average of 4 years (Shah, 2016), advancing from 2.7 years before 1999 (Gordon, 2009). This is consistent with a maturing industry in which the perceived value of incremental technological enhancements declines over time.

The U.S. Department of Labor conducted surveys in 1984, 1989, 1993, 1997, 2001, and 2003 to estimate the numbers of workers who used a PC at work (Bureau of Labor Statistics, 2005; Friedberg, 2003; Hipple & Kosanovich, 2003). The results of that research work can be seen in table Figure 10. If the introduction of the IBM PC is used as the starting point for the business, education, and government diffusion curve, based on their extensive direct sales force and retail channels, then it appears that this segment got off to a rapid start, growing from no significant installed base, to 24.4% in just three years. This rapid pace of expansion continued for the next ten years with double digit annual increases in penetration. The more recent observations show the rate of adoption slowing to 1% - 2%. The overall adoption rate seems to be frozen at just over 50% of workers. This represents only ~50% market penetration in the Rogers (2003) model.



Year	1984	1989	1993	1997	2001	2003	mid-point
Total	24.4	37.3	46.6	50.6	53.5	55.5	1997
years	2	5	4	4	4	2	
growth rate	24%	11%	6%	2%	1%	2%	

Year	1984	1989	1993	1997	2001	2003	mid-point
Professional & technical	38.1	54.4	65.7	73.1	78.9	78.7	1988
Managers & administrators	42.5	61.8	73.7	78.7	80.4	80.8	1986
Sales	23.9	35.5	49.8	55.8	57.7	59.7	1993
Clerical	47.4	66.8	77.4	78.6	73.6	73.5	1985
Craftsmen	10.1	15.2	23.5	25.3	29.9	31.9	tbd
Operatives	5.8	9.6	15.7	18.6	19.5	21.5	tbd
Laborers	3.2	6.6	11.7	12.8	13.7	15.7	tbd
Service	6.0	9.8	15.1	16.8	23.3	27.5	tbd

Figure 12. PC usage rates overall, in business, and by job function. Compiled data from the U.S. Census and the U.S. Department of Labor.

Part of the challenge is that PC usage appears to vary widely depending on the role of employees in the workforce. These results are summarized in table Figure 12. The adoption rates hover at approximately 80% for Managers and Administrators and fall to just under 16% for laborers. In addition, adoption tends to vary by industry as well. In the Financial and Information Industries, the top two industries for adoption in 2003, the penetration rates were 82.4% and 77.5%, respectively (Bureau of Labor Statistics, 2005). At the other end of the spectrum, the two industries that scored lowest for adoption were Agriculture and Construction, with penetration rates of 20.2% and 28.1%, respectively

(Bureau of Labor Statistics, 2005). The 2003 survey showed overall penetration rates of 73.5% for federal government workers and 67.2% for state government workers. Lehr and Lichtenberg (1996) provide a detailed assessment of the adoption of technology by government workers from 1987 – 1992.

A summary of diffusion curves broken out by segment is provided in Appendix D. If the home (hobbyist) PC market starts in 1975, and the business/government PC market starts in 1982 with the introduction of the IBM PC, then this analysis illustrates that it took 25 years to reach 50% penetration in the home PC market, and another 13 years to reach 84% (late majority), and could still reach full penetration by 2025. 2025 is 25 years after the mid-point of the curve in 2000. This would essentially approximate a normal distribution curve as outlined in Rogers (2003).

On the other hand, in the business/government segment it took just 16 years to reach 50% penetration overall, 8 years to reach 50% penetration of professional workers, 5 years to reach 50% penetration for administrators & managers, and only 4 years to reach 50% penetration for clerical workers. The portion of the business/government market associated with craftsmen or laborers are 29.9% and 13.7% even after 20 years from first introduction.

In Appendix D, these adoption curves are forecast to 2020 based on the data available for the most recent growth rates. Based on this analysis, none of these curves reaches 84% even after 20 years. However, even if they did, this would not represent a normal distribution curve. A normal distribution curve would require the market segment to reach full penetration in just 16 years after the mid-point, professional workers to reach

full penetration within 8 years after the mid-point, full penetration of the managers & administrators in 5 years after the mid-point, and full penetration for clerical workers within 4 years after the mid-point. Craftsmen and laborers do not reach even 50% after 40 years of market diffusion.

This analysis suggests that, while there appears to be a single (almost normal) curve for home PC users, in the business/government market things are quite different. Rather than having one single diffusion curve, there are a series of different diffusion curves based on job function, industry, and age (Friedberg, 2003). These curves do not appear to approximate a normal distribution. Generating the entire series of curves for each of these distinct populations is beyond the scope of this research project. In the remainder of this analysis, the diffusion curve for the home PC market is used as a proxy for overall market diffusion. The points of possible confusion with using this curve are outlined in more detail later in this analysis.

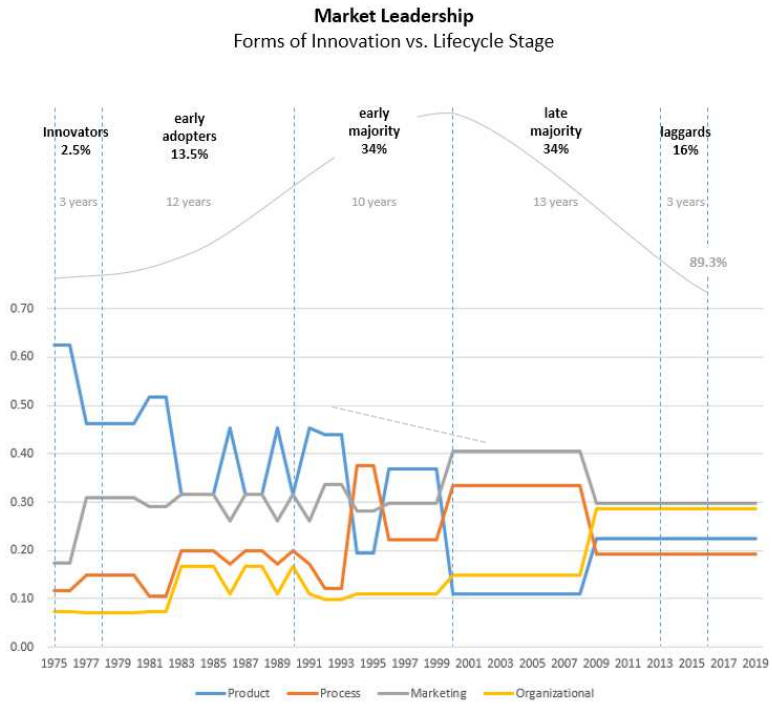


Figure 13. e-Delphi results mapped against overall U.S. PC market life-cycle.

In Figure 13 the results of the e-Delphi study are mapped to the market diffusion model (Rogers, 2003) for the home PC market. This market for household PC's took 25 years to reach 50% penetration,13 years to reach another 34% of the population, and 3 years to reach most laggards. The pattern of technological product innovation decreasing in importance is evident throughout the 44-year lifecycle from 1975 - 2019. The increasing importance of marketing innovation can also be seen throughout the lifecycle. This is not to say that technology is not important, in a technology industry like the PC industry, technology is critical. Competitors in this type of market must continue to offer the latest technology to remain relevant.

However, the evidence in this study suggests, that in order to be a market share leader, competitors will need to find another form of innovation besides technological product innovation to differentiate as markets mature. In fact, as markets mature, marketing and organizational innovation become much more important factors for establishing market leadership. One possible exception may be the case of disruptive innovation as described by Christensen (1997). In that case, the market resets to a new S curve, and the lifecycle begins all over again, with technological product innovation leading the way. Some additional research will be required to validate this pattern.

Summary

In this chapter the research process was reviewed, and the results were presented and analyzed. The e-Delphi process first required a data set of market share leaders for the period from 1975 – 2019. The data set was compiled using an overlay technique based on multiple sets of publicly available information. An expert panel was then asked to (a) confirm the market share numbers, (b) confirm the forms of innovation presented in the 3rd edition of the Oslo manual, and (c) rank each market share leader in the data set with respect to the form of innovation that was used to achieve leadership. A Likert scale was used to capture expert panel preferences, a pairwise comparison transformation was applied to the results, and an AHP decision matrix was used to calculate a mathematical consensus for each market leader.

The results confirm the general focus of innovation outlined in the A-U model. Technological product innovation led to market leadership in the early stages of the market and this gave way to process innovation as the market matured. The study also

showed that as the market matured, marketing innovation, and in the case of HP, organizational innovation, played a much larger role in market leadership. These latter forms of innovation, marketing and organizational, were not included in the original A-U model. This suggests that both of these new forms of innovation could be even more effective for establishing market shared leadership in mature markets then traditional product or process innovation.

In the final chapter these results are explored further to highlight the full implications of this work. The limitations and boundaries of the results are also outlined in more detail. The chapter ends with recommendations, implications, and conclusions that emerged from this research study.

Chapter 5: Discussion, Conclusions, and Recommendations

Companies identified as business model (organizational) innovators produce returns four times greater than those identified as product or process innovators and the results are more sustainable (Lindgart, et al., 2009). The purpose of this e-Delphi expert panel research project was to build consensus with a panel of technology experts on the forms of innovation used to establish market leadership over the historical lifecycle of a technology industry. The industry chosen for this study was the U.S. PC industry over the period from 1975 – 2019. The results may be used to extend the A-U model (see Utterback & Abernathy, 1975) and create a baseline for other forms of innovation that produce greater and more sustainable returns within that framework.

In this project, I used a qualitative e-Delphi study with an AHP decision model to help build consensus among a panel of expert innovators and researchers. Experts who participated in this study were asked to identify the sources of innovation used by market share leaders in the U.S. PC industry over the period from 1975 - 2019. The Delphi method is well established as a qualitative tool that can help build consensus among panels of experts (Linstone & Turoff, 2011; Skinner, et al., 2015; Strasser, 2017). On the other hand, AHP can be used to form a mathematical consensus when decisions are based both on fact and on judgement (Saaty, 2008). The combination of both techniques removed the subjectivity that can be associated with the Delphi method (Hsu & Sandford, 2007) and assured that mathematical consensus was achieved.

This project provided an opportunity to compile a data set of market share leaders in the U.S. PC industry over the entire lifecycle (1975 – 2019). The matching

diffusion curve for the U.S. home PC market was also formulated based on U.S. Census data. This combination of data sets could be used by future researchers to explore other aspects of innovation, competition, and strategy.

The results of this research show that a panel of technology experts agree that the four forms of innovation relevant for evaluating market share leaders over the lifecycle of a technology industry are (a) product, (b) process, (c) marketing, and (d) organizational innovation. These four factors align with the forms of innovation proposed in the 3rd edition of the Oslo manual published by OECD (2005).

The results demonstrate that an AHP decision model can be used with e-Delphi to speed consensus. The results also show the effectiveness of using a Likert scale in combination with the pairwise comparison technique. This enhanced process can be used to reduce the number of individual comparisons required, reduce the risk of inconsistency in the results, and allow for the case where both elements of a comparison are completely unimportant (effectively zero).

The results show that Rogers' (2003) diffusion model can be used to describe the evolution of the U.S. home PC market using census data. However, the model does not appear to be rich enough to describe diffusion within business, education, or government markets. In these segments, there are many related adoption curves based on factors such as job description, industry, and age.

The results of this study confirm the findings of the A-U model for market share leaders in a technology industry. The market share leaders focused on technological product innovation early in the product lifecycle. This focus shifted to process

innovation as the market expanded. The results also demonstrate that market leaders pivoted to marketing and organizational innovation late in the lifecycle. This pattern is consistent with establishing a competitive edge, in a market where the perceived value of the next incremental innovation is small, and all production or organizational efficiencies have been effectively exhausted.

Interpretation of Findings

OECD, an international standards agency, has published the Oslo manual for over 25 years, and each new edition has offered a different definition for innovation (OECD, 1992, 1997, 2005, 2018). The early focus was on technological innovation applied to either product or process innovation in traditional manufacturing organizations. This was consistent with the academic literature at that time. The latest version of the Oslo manual recognized both product and process organization, but characterized anything beyond product innovation as a process innovation. The paradigm of marketing and organizational innovation existing only as a form of process innovation is not embraced in the literature. The expert panel in this study, when presented with alternate definitions of innovation, preferred the characterization of product, process, marketing, and organizational innovation. This interpretation is consistent with the 3rd edition of the Oslo manual (OECD, 2005).

Fagerberg (2003) and Fagerberg (2018) concluded that innovation is generally considered in three ways: (a) as a process consisting of an initial innovation followed by a series or incremental innovations, (b) in terms of whether the innovation is incremental or disruptive, or (c) based on the type of innovation involved. In the first scenario, an

innovation is brought to market, a number of initial designs compete for market dominance, the market consolidates on a dominant platform, and then incremental innovation proceeds based on the dominant platform (Anderson & Tushman, 1990). Incremental innovation is generally described as advancement along an existing S curve (Fagerberg, 2003). Christensen (1997), introduces the concept of a disruptive innovation that moves the market focus from an existing S curve, to a new S curve, and the same evolutionary pattern occurs all over again. Disruptive innovation tends to favor new market entrants, while incremental innovation favors incumbents (Christensen, 1997).

Overall, the results in this study focused on a single S curve of innovation for the PC market. Product and process innovation appear more effective for market share leaders early in the lifecycle. Organization innovation appears more effective for these market share leaders in the latter end of the lifecycle. Marketing innovation was a dominant form of innovation from the period 1983 – 2019. In fact, it was the primary form of innovation used by both IBM and Dell to establish market leadership.

The duel for market leadership between IBM and Commodore seems to reflect two distinct diffusion curves rather than a wavering importance between product and marketing innovation. The focus of Commodore was the home PC market which was still in the early adopter stage in 1983 – 1991. The total market adoption over this period of time for the PC in the home was less than 16%. Commodore focused on technological product innovation releasing a continuous stream of new technology and game titles. In this market, new games represent a form of product innovation that drive user value.

On the other hand, IBM used standardized parts and an operating system designed by others, to reach the business and government market segment. They used their strong brand, and extensive sales force to target larger customers, and then used retail computer stores, along with their own branded retail business centers, to push technology to small to medium business customers. The business and government segment grew from almost zero to 24% in just three years (Friedberg, 2003). The overall business/government market expanded to over 50% penetration by 1997 (Bureau of Labor Statistics, 2005). However, the penetration among professional and technical workers was already over 50% by 1989 and 73% by 1997. The primary applications were email, word processing, spreadsheets, and calendaring (Bureau of Labor Statistics, 2005).

With this more mature adoption curve fur business/government organizations, marketing innovation proved superior to technical product innovation for establishing marketing leadership. A similar pattern is visible for Dell from 2000 – 2008. If the two markets are split, consumer and business/government, then technical product innovation remains a potent tool for Commodore in this early stage home computer segment; and marketing innovation appears to be a more effective for establishing leadership in the more mature business/government segment of the market. Apple continued to focus on product innovation for the home market, while Packard Bell and Compaq focused on process and marketing innovation in the business/government market. Although Compaq did invest in technology as well; they were perceived as the leader of the IBM PC clones.

Since this study was focused on a single S curve, there is no indication of whether incremental process, marketing, or organization innovations would be more effective than

a move to another S curve, if that is possible. The literature suggests that the move to a new S curve would not favor existing market leaders (Christensen & Raynor, 2003). However, sustainable competitive advantage comes from organizing strategies around core competencies (Hitt et al., 2016; Rothaermel, 2018). If a firm identifies technological product innovation as a core competency, then it may work to their advantage to move to a new S curve, early in the lifecycle, when product innovation is still a dominant form of innovation. Based on these results, it is not clear that a firm that is expert in product innovation will be able to establish a leadership position market in later stages of market diffusion without core competencies in other forms of innovation as well.

Consider the case of Uber which used business model innovation, a form of organizational innovation, to disrupt the taxi industry in the same way that a technological product innovation might. The innovations offered by Uber effectively moved the taxi industry to another S curve. The company is a technology-enabled service provider, yet technology is not their primary offering. Technology is used to enable a platform business that matches riders with part-time drivers. The case of Lyft shows that the technology alone is not a sustainable form of innovation in this space. Instead, it is the network effect, the comes from having a large volume of riders and drivers.

The research of Utterback and Abernathy (1975) and Utterback (1994) showed that firms concentrate on product innovation early in the lifecycle, but once a dominant design is established, the focus turns to process innovation. The expert panel results from this study indicate that leaders in the U.S. PC industry used technological product innovation early in the lifecycle to experience success. The results showed a growing

importance on process innovation in the early majority stage of adoption as the market expanded and the importance of product innovation declined. This is consistent with the findings of Utterback and Abernathy (1975).

The results of the study indicate, that while marketing innovation was prevalent from 1983 forward, it became the dominant form of innovation, along with process innovation, for the bulk of the late majority period. Marketing innovation was combined with organizational innovation in the tail-end of the late majority period and the laggard period. Even though marketing and organizational innovation score higher in this later time period, the appearance of all four forms of innovation is more balanced in this period then earlier in the lifecycle. Marketing and organizational innovation were not included in the original A-U research, so this represents a potential extension of that model to cover additional forms of innovation.

The pattern reflects the diminishing marginal value for smaller incremental product innovations over time (Christensen, 1997). Process innovation can also experience diminishing marginal effectiveness as all the inefficiencies are squeezed out of the process over time (Mantovani, 2006). These process efficiencies can be used to increase margins, reduce costs for customers, or some combination of the two. This opens the way for marketing innovation, and potentially, organizational innovation, to play a stronger role in the competitive landscape. This pattern of innovation can be combined with the original A-U model to create the Expanded A-U model outlined in Figure 14. One additional distinction is that the traditional A-U model was focused on

innovation alone, and this expanded model is focused on innovation that can be used establish and maintain market leadership.

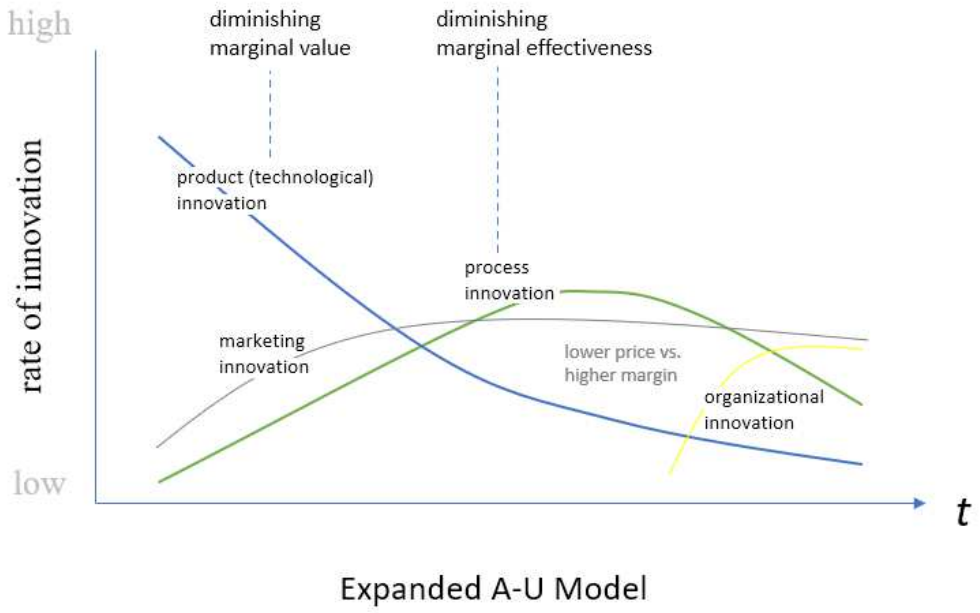


Figure 14. The original A-U model, augmented with marketing and organizational innovation, to create an expanded A-U model of innovation.

The spread of an innovation (product, process, or idea) is referred to as diffusion in the marketing literature (Peres et al., 2010). Rogers (2003) outlined a model for diffusion of innovations which has become widely established in the marketing literature (Wright & Charlett, 1995). Diffusion follows a normal distribution in Rogers model based on a sigmoid (S) curve (Rogers, 2003). Rogers' model appears to work best with historical data, but can be difficult to use for forecasting applications (Wright & Charlett, 1995). The Bass model is another popular diffusion model in academic literature and appears to have more predictive power (Bass, 1969; Mahajan et al., 1990; Ofek, 2016).

A diffusion curve for the U.S. home PC market was developed in this study. Developing a diffusion curve for the business, education, and government users appears to be much more difficult. There appears to be multiple diffusion curves based on the type of job function, industry, and age, among other factors. Rogers diffusion theory may work well with simple discrete markets, like the home PC market; however, the model may not be sophisticated or complete enough to address the topic of diffusion in more complex markets with multiple diffusion curves.

This research study is based on a e-Delphi research method using an AHP decision model. The literature is rich with examples of the Delphi method in practice (Donohoe & Needham, 2009; Gallego & Bueno, 2014; Hallowell & Gambatese, 2009; Strasser, 2017). In a similar fashion, there are many examples of the AHP method in research and practice (Saaty, 2008; Saaty & Vargas, 2012). Both methodologies are typically used for making complex decisions in situations that involve both fact and expert insights. The combination of both e-Delphi & AHP techniques removed the subjectivity sometimes associated with the Delphi method (Hsu & Sandford, 2007) and allowed for convergence in a single two-stage round.

Some in the psychological community assert it is easier and more accurate to express opinions on only two alternatives rather than simultaneously on all alternatives (Ishizaka & Labib, 2011). That general belief has given rise to the use of the pairwise comparison in AHP. The use of pairwise comparison in a study of this nature still poses some unique challenges. To address these limitations a (1 – 9) Likert scale was used and

then the resulting values were transformed into pairwise comparisons using the technique of Kallas (2011).

This technique reduced the number of participant judgements required. With direct pairwise comparison N(N-1)/2 individual comparisons would be required. In this research study, with eleven separate companies to rank, that would translate into 66 comparisons. Using the modified Likert technique, the amount of comparisons was reduced to 44.

When making large numbers of pairwise comparisons the consistency of judgements can become an issue. When selecting the relative importance of two variables at a time, when the rest of the universe of choices are not visible, inconsistency in the individual judgements can be common. Saaty (1980) proposed a consistency ratio to determine the level of consistency. A perfect consistency score, while not common, is zero. The results in this research study consistently show consistency scores near zero and much less than the threshold value of .10.

Pairwise comparison requires judging the relative importance between two decision elements. This type of decision making breaks down when there are two elements that are of equal importance or where neither is important. In the former case, the two elements can be judged to be of equal importance, but it is difficult to know if they are equally very important, or equally unimportant, or somewhere in between. The structure of pairwise comparison also makes it difficult to indicate that an item is "completely" unimportant (essentially zero).

The combination of using a Likert score with a transformation technique allowed this study to be completed faster, using a more intuitive and informed process from the user's perspective, and the results contained less potential for consistency errors.

Limitations of the Study

This research study was based on a e-Delphi research method using an AHP decision model. The literature is rich with examples of the Delphi method in practice (Donohoe & Needham, 2009; Gallego & Bueno, 2014; Hallowell & Gambatese, 2009; Strasser, 2017). In a similar fashion, there are many examples of the AHP method in research and practice (Saaty, 2008; Saaty & Vargas, 2012). Both methodologies are typically used for making complex decisions in situations that involve both fact and expert insights. With AHP, the technique is often used with multi-stage, hierarchical decisions. In this case, the decision regarding the form of innovation has already been made by the (operators) innovators in the technology industry being investigated. The original competitive decision on the form of innovation would have been based on internal and external environmental factors, besides lifecycle stage, that were not visible to the expert panel in this study. This study only considered the choice of the form of innovation, and the stage of the lifecyle, and does not consider other qualitative elements.

When using expert opinion, there is always the possibility of bias on the part of individual experts. The Delphi process depends on this richness of diversity of opinions in the expert panel to make sure that the outcome embodies multiple viewpoints (Dalkey, 1967; Linstone & Turoff, 1975; Linstone & Turoff, 2002). One other risk is that too many rounds can lead to panel fatigue and a dwindling panel of experts. Research by

Brockhoff showed only a minimal increase in convergence beyond three rounds (Linstone & Turoff, 2002). The version of e-Delphi used in this research project is based on an AHP decision model to assure (mathematical) convergence using two stages in a single round. The fall-off in participation was minimal between stage one and stage two and throughout the multiple comparisons required in Stage 2. The mathematical process utilized in AHP, allows for rapid conversion, but may not allow for the same level of interactive discussion available in more traditional forms of Delphi.

This study only focused on the forms of innovation used by market leaders to establish a leadership position in the timeframe under investigation. There may be other competitors who chose a similar strategy and did not become market leaders. There is no guarantee that there is a causal relationship between the form of innovation chosen by these market share leaders, in each phase of the lifecycle, and future competitors faced with similar competitive choices, at similar stages in the lifecycle. This study highlights only what worked for market share leaders over the lifecycle of the U.S. PC industry.

This study was based on the U.S. PC market from 1975 – 2019. The results of the analysis may change if the focus was worldwide or an even more limited geographical region. Lenovo was included in the final analysis because they are the current worldwide leader and appear to be gaining momentum on HP in the U.S. PC market. In addition, this analysis focused on diffusion for a single S curve for the PC industry. There was not attempt made to map the results to prior S curves or any number of alternate S curves that could be present in the future.

Recommendations

The original work on the A-U model (Utterback & Abernathy, 1975) is based on a data set of 567 commercially successful innovations from five industries and 120 firms collected by the National Science Foundation (Myers & Marquis, 1969). This research study was based on market share leaders (11) over the 44-year history of the PC industry. Utterback and Abernathy estimated the stage in the lifecycle for each innovation. The historical longitudinal data set used in this study demonstrates the transition that takes place from one stage in the lifecycle to the next. This provides necessary context for the transition between stages; however, it is only a single industry. It would be useful to repeat similar studies across a broad range of products/industries to assure the results generated are not specific to the PC industry or even the technology industry.

This focus of this study was the forms of innovation that led to market share leadership in the U.S. PC industry. The only firms explored were those with significant market share at some point in the lifecycle. It could be useful to explore all the competitors in the market to see if there were other competitors that used similar forms of innovation but did not emerge as market leaders. This could provide insight into any type of more extensive causal relationship that exists between the forms of innovation and all competitors in the market. This may be difficult to accomplish using the current technique because at times there were more than 250 competitors, and many had very little market share or visibility (Steffens, 1994). It may be difficult to find experts who have a recollection of all 250 competitors and the forms of innovation they employed.

Rogers' (2003) diffusion theory assumes that adoption follows a normal distribution. In this study, adoption across the home PC market in the U.S. could approximate a normal curve, it is still too early to be positive. However, evidence from the business PC market shows that this adoption curve is far from normal. The curve for white color workers demonstrates an immediate spike to reach 50% penetration, ranging between 4 – 8 years, with a long tail of much slower adoption. In the case of craftsmen and laborers, the curve may not have reached 50%, even after 40 years. It would be useful to examine a number of industries, break them into finer sub-segments, and see if Rogers assumption of a normal curve still holds true. It might also be useful to explore market cross-sections based on multiple factors (e.g. use factors such as role and age to create multi-attribute cross-sections of market segments).

There is still considerable disagreement in the literature regarding business model innovation. In particular, there does not seem to be a unified definition for the concept of a business model. There does seem to be a recognition that there is logical construct called a business model, and most agree that it is important, but they just can't seem to agree on what it is. If the definition of the term business model is still in flux, then it becomes even more difficult to identify what business model innovation could mean. In this study, our experts were satisfied with treating business model innovation as a form of organizational innovation, which seems to be an accurate characterization. Given the amount of discussion in both business and scholarly literature on business model innovation, it would be useful to standardize the definition, and then test (a) the

prevalence of business model innovation by lifecycle phase, and (b) understand the difference, if any, between business model innovation and organizational innovation.

The latest version of the Oslo manual (OECD, 2018) recognized both product and process organization, but characterized anything beyond product innovation as a process innovation. This definition does not seem to be supported by the literature, or the analysis provided in this study; and it was rejected by our expert panel in favor of the definition provided in the 3rd edition of the Oslo manual (OECD, 2015). Additional work may need to be done to further refine the definition in a way that is both supported by the literature and can be embraced by experts from industry and academia.

A social network of professional users was utilized to recruit participants. The network used in this case was both extensive and diverse. A simple social media post requesting participants produced only a modest response. However, a personal invitation to network connections produced a much larger response more quickly. It would be ideal to have a tool that could traverse the nodes of specific social networks and judge the overall diversity and goodness for research purposes. It would also be useful to conduct additional research on the characteristics required to generate a truly random panel of experts from a network that starts with a single node. Social media has the potential to profoundly change how panels of consumers and professionals are created for research purposes.

This study used a hybrid e-Delphi technique, with an AHP decision model, and Likert scale conversion. This technique appeared to experience less drop-out than traditional Delphi based on the rapid convergence. The Likert scale reduced the number

of individual judgements required, allowed experts to evaluate choices within the context of all the alternate choices, and lower the potential for inconsistency. This technique should be objectively tested further, side-by-side with traditional Delphi and AHP (pairwise) techniques, to further validate participation rates, accuracy, and overall satisfaction with the technique by panel participants.

Implications

Innovation has been responsible for 80% of U.S. economic growth since World War II (Atkinson, 2011). Innovation can lead to significant new products that expand existing markets or create completely new ones (Christensen, 1997; Christensen & Raynor, 2003). The top five publicly traded U.S. firms in terms of market capitalization are Apple, Alphabet (Google), Microsoft, Amazon, and Facebook (Desjardins, 2016; Desjardins, 2019; Kiesnoski, 2017). In 2018 Apple became the first company in history to break $1 trillion in market capitalization (Salinas, 2018). In 2019 Microsoft crossed the $1 trillion market capitalization threshold to become the most valuable company in the world (Kilgore, 2019). Combined, the market value of these five companies, now exceeds the gross domestic product of the United Kingdom (Associated Press, 2018). These five companies also represent the most valuable global brands (Frangoul, 2017) and employ more than 1.2 million people (CNN Business, 2020). Of these top technology companies, only two, Microsoft which was started in 1975, and Apple which was started in 1976, existed before 1994. Amazon was started in 1994, Alphabet (Google) was started in 1998, and Facebook was started in 2004. These companies were all propelled to leadership positions by innovations that they created and brought to market.

The U.S. Bureau of Labor Statistics reports that over 48 million jobs, 46% of the U.S. labor force, were created by firms that started after March 1993 (Sadeghi, 2010). Economic expansion creates jobs, reduces unemployment, and increases wages (Keynes, 1960). Research based on The Federal Bureau of Investigation (FBI) universal crime reports has shown that declining unemployment rates and increasing wages are associated with lower rates of property-related crime (Lin, 2008; Mustard, 2010; Raphael & Winter-Ebmer, 2001). Lower levels of unemployment can also improve physical health, mental health, and reduce the risk of stress related death (Bartley, 1994). An increase in income and output also leads to larger amounts of charitable giving (Daniels, 2015; Havens, et al., 2006).

The focus of this research study was to identify the form(s) of innovation that allowed market share leaders to dominate the U.S. PC market over the lifecyle of the industry. Two of the innovative technology companies highlighted earlier in this section, Apple and Microsoft, owe their success to the PC evolution that was explored in this project. This research provides new insights that have the potential to aid innovators in choosing the right form of innovation depending on the stage of the lifecycle. This could be an essential piece of knowledge that guides the next generation of innovators, creates significant additional wealth, and drives job creation/employment.

The results of this research show that a panel of technology experts agree that the four forms of innovation relevant for evaluating market share leaders over the lifecycle of a technology industry are product, process, marketing, and organizational innovation. These four factors align with the forms of innovation proposed in the 3rd edition of the

Oslo manual published by OECD (OECD, 2005). The A-U model, which has been used to guide researchers and innovators for over 40 years, only included technical product and process innovation. The A-U model is based on the observation that organizations tend to focus on (technological) product innovation early in the lifecycle and focus more on process innovation as markets mature.

This study, based on the opinions of an expert panel, confirm the findings of the A-U model. The results of this study also demonstrate that marketing innovation played a significant role in the dominance of market share leaders later in the lifecycle (e.g. IBM, Dell, HP). Organizational innovation also played a role, combined with marketing, at the latest stages of the lifecycle for HP. This is consistent with a mature product offering, where new incremental innovations are associated with low customer value, and most of the significant process and scale economies have been realized. In this case, firms can use marketing innovation, and organizational innovation, to create unique customer value and secure/sustain market leadership. Organizational innovation can also be used as a form of disruptive innovation, to shift the S curve, and establish market leadership for a new market entrant. This study has the potential to establish a baseline for marketing and organizational innovation in the A-U framework.

The analysis in this study calls into question a key assumption used in Rogers (2003) diffusion model. The overall model of PC adoption by households in the U.S. seems to approximate normal curve as opined by Rogers (2003). The research also uncovered the fact that the diffusion curve for the business/government market does not appear to approximate a normal curve. In fact, rather than a single diffusion curve, there

appear to be multiple diffusion curves, based on different segments in the population. Even when the results are taken in the aggregate (e.g. all business/government workers), the market adoption rate still does not appear to approximate a normal curve. This implies that Rogers (2003) model may not be sufficient to model or explain product diffusion within this market segment. Additional research will be required to determine exactly where this framework breaks down. Rogers model is widely established in the marketing literature (Wright & Charlett, 1995) and the book, *Diffusion of Innovations*, is now in its 5th edition, with the distribution of each edition reaching more than 30,000 (Goodreads, 2019). Current followers will need to be cautious how this model is applied.

The results of this study demonstrate that an AHP decision model can be used with e-Delphi to speed (mathematical) consensus. The results produced are also a ratio scale which can be used for mathematical analysis and direct proportional comparison. The reduction in the time required to reach consensus can make the whole process less taxing on participants and reduce drop-out rates.

Instead of using a direct pairwise comparison, this study used a Likert scale and the transformation technique proposed by Kallas (2011). This technique solves several important limitations of the pairwise comparison model commonly used with AHP. This enhanced process can limit/reduce the number of individual comparisons required, significantly reduce the risk of inconsistency in the results, and allow for the case where both elements of a comparison are completely unimportant (effectively zero).

Conclusions

Innovation has been responsible for 80% of U.S. economic growth since World War II (Atkinson, 2011). Without innovators, and effective tools, economic growth will not continue to power the growth in our economy and improve the quality of life for even those at the bottom of the pyramid. Perceptions of innovation have changed dramatically since Schumpeter's writings in the 1930's, Rogers' theory of diffusion from the 1960's, and Utterback & Abernathy's work from the 1970's. It is now well-accepted, in theory and in practice, that the concepts of technical product and process innovation alone are no longer rich enough to describe the workings of modern innovation. These theories were not wrong, they served as a critical starting point, that needs to evolve, as experience and research illuminate other paths and possibilities.

The results of this study suggest that Rogers model of diffusion may need more exploratory research in complex multi-segment markets. The assumption of a normal distribution for diffusion appears too simple for this type of market analysis. This study also exposed a faster and more effective way to conduct Delphi research and work with pairwise comparisons when using AHP.

The results of this study of a technology industry, support the concept of four forms of innovation: product innovation, process innovation, marketing innovation, and organizational innovation. The results indicate that market leaders focus on product innovation early in the lifecycle, and that focus shifts to process innovation as markets mature. The results of this study further illustrate that marketing and organizational

innovation can be used to establish market leadership when most of the benefits associated with product/process innovation have been exhausted.

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Appendix A: e-Delphi Draft Screens

screen design – introduction

Welcome to the ***Forms of Innovation*** research project. Thank you for agreeing to participate. You are part of an exclusive group of technology experts who have the ability help shape the way that future generations approach innovation.

screen design – introduction

Background (1):

Innovation has been responsible for 80% of US economic growth since World War II (Atkinson, 2011). Innovation can lead to significant new products that expand existing markets or create completely new ones (Christensen, 1997; Christensen & Raynor, 2003). The top five publicly traded U.S. firms in terms of market capitalization are Apple, Alphabet (Google), Microsoft, Amazon, and Facebook (Desjardins, 2016; Kiesnoski, 2017). In 2018 Apple became the first company in history to break $1 trillion in market capitalization (Salinas, 2018). In 2019 Microsoft crossed the $1 trillion market capitalization threshold to become the most valuable company in the world (Kilgore, 2019). These five companies also represent the most valuable global brands (Frangoul, 2017). Of these top companies only two; Microsoft which was started in 1975, and Apple which was started in 1976; existed before 1994. Amazon was started in 1994, Alphabet (Google) was started in 1998, and Facebook was started in 2004. These companies were all propelled to the top by significant innovations that they created and brought to market.

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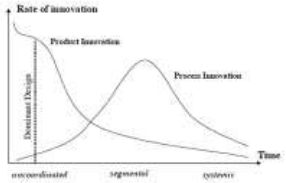
screen design – introduction

Background (2):

The Organization for Economic Cooperation and Development (OECD), the foremost international authority on measuring innovation (OECD, 2019), officially recognized only technological product and process innovation from 1997 to 2005 (OECD, 1997). Utterback (1994), building on Utterback and Abernathy (1975), showed that firms focus on product innovation early in the lifecycle, and then shift focus to process innovation as markets mature. This body of research, which guides innovators and researchers, is generally referred to as the A-U model (Akiike, 2013). In the third edition of the Oslo manual, the OECD officially recognized product, process, marketing, and organizational innovation (OECD, 2005). The absence of non-technological forms of innovation, in foundational tools such as the A-U model, exposes a research gap.



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screen design – introduction

Background (3):

In this study you will be asked to (a) validate the market share leaders based on public information, (b) establish the forms of innovation that will be considered, and (c) identify the form of innovation that helped establish market leadership over the 40-year (1975 – 2015) history of the PC industry. The goal is to identify patterns (if any) in the focus of innovation activities by the market leaders over the entire lifecycle (to this point).

screen design – introduction

Instructions:

Please answer the questions on the screens that follow. You can enter comments (if any) in the space that is provided. These comments will be shared with other participants only if required to establish a consensus. Comments are anonymous and no names will be shared. Participants will each be able to see the results and will receive a copy of the finished research report.

screen design – *third step*

Please Validate the Following Market Share Information

PC Industry Market Share Leaders 1975 to 2015
U.S. units sold

date range	1975 to x details	$(x+1)$ to x^1 details	(x^2+1) to x^2 details	(x^3+1) to x^3 details	... *as needed*	(x^n+1) to 2015 details
market share leader	company 1 %	company 2 %	company 3 %	company 4 %		company *n* %

view (download) entire data set

Market share numbers are based on results reported publicly by International Data Corporation (IDC), Gartner Group, and Ars Technica. *note: links to their respective websites*

Do these numbers appear accurate to you? Yes ☐ No ☐

Please share concerns (if any) in the box below:

250 character (max)

screen design – *third step*

Please Validate the Forms of Innovation

Organization for Economic Cooperation and Development (OECD)

Oslo Manual, 3rd edition (2005) *note: links to Oslo Manual, 3rd edition*

Product Innovation – changes in the product produced (detail)

Process Innovation – changes in the production process (detail)

note: (detail) links to detailed description from Oslo Manual, 3rd edition

Marketing Innovation – changes in marketing mix (packaging, people, price, place, promotion, ...) (detail)

Organizational Innovation – changes in the structure/operation of the organization (detail)

*Note: in this framework, **business model innovation**, is composed of some combination of the other forms of innovation. Study participants will be able to select the percentage of each form of innovation for each market share leader.*

Do these definitions appear accurate to you? Yes ☐ No ☐

Please share concerns (if any) in the box below:

250 character (max)

Frequently Asked Questions (FAQ):

Who is the Organization for Economic Cooperation and Development (OECD)?

What is the OECD Oslo Manual?

Why the 3rd edition?

...

note: links to FAQ answers, questions will be added as they arise...

screen design – *third step*

Summary Results

Your Results

Group Results

Comments Received

Comment 1 ...

Comment 2 ...

...

Comment n

screen design – introduction

Instructions:

Please answer the questions on the screens that follow.

(1) Please select the **level of importance** for each form of innovation, **for establishing market leadership**, for each market share leader, for each time period.

(2) Considering the innovative efforts of the company, please indicate what percentage of innovative activity **you believe** was devoted to each form of innovation.

Please make sure to rank every market share leader for all forms of innovation presented.

Use your experience, research articles/documents, or other reliable resources to make your choices.

screen design – *fourth step*

Please Rank the Form of Innovation

PC Industry Market Share Leader 1975 to *x*
U.S. units sold

date range	1975 - x	(x + 1) - x^1	(x^1 + 1) to x^2	(x^2 + 1) to x^3	... *as needed* x^n to 2015
market share leader	company 1 %	company 2 %	company 3 %	company 4 %	company n %

What form of innovation was used to establish market leadership for company 1 in 1975?

	not important 1	2	3	4	5	6	7	8	very important 9	**% of effort?**
Product Innovation (detail)	☐	☐	☐	☐	☐	☐	☐	☐	☐	
Process Innovation (detail)	☐	☐	☐	☐	☐	☐	☐	☐	☐	
Marketing Innovation (detail)	☐	☐	☐	☐	☐	☐	☐	☐	☐	
Organizational Innovation (detail)	☐	☐	☐	☐	☐	☐	☐	☐	☐	
										100%

Note: in this framework, ***business model innovation****, is composed of some combination of the other forms of innovation.*

Note: must total to 100%

screen design – *fourth step*

Please Rank the Form of Innovation

note: this pattern repeats for each market share leader...

PC Industry Market Share Leader 1975 to *x*
U.S. units sold

date range	1975 - x	$(x+1)-x^1$	(x^1+1) to x^2	(x^2+1) to x^3	... *as needed* x^n to 2015
market share leader	company 1 %	company 2 %	company 3 %	company 4 %	company n %

What form of innovation was used to establish market leadership for company 2 in (x + 1)?

	not important 1	2	3	4	5	6	7	8	very important 9	**% of effort?**
Product Innovation (detail)	☐	☐	☐	☐	☐	☐	☐	☐	☐	
Process Innovation (detail)	☐	☐	☐	☐	☐	☐	☐	☐	☐	
Marketing Innovation (detail)	☐	☐	☐	☐	☐	☐	☐	☐	☐	
Organizational Innovation (detail)	☐	☐	☐	☐	☐	☐	☐	☐	☐	

Note: in this framework, ***business model innovation****, is composed of some combination of the other forms of innovation.*

100%

Note: must total to 100%

screen design – *fifth step*

Summary Results

Your Results

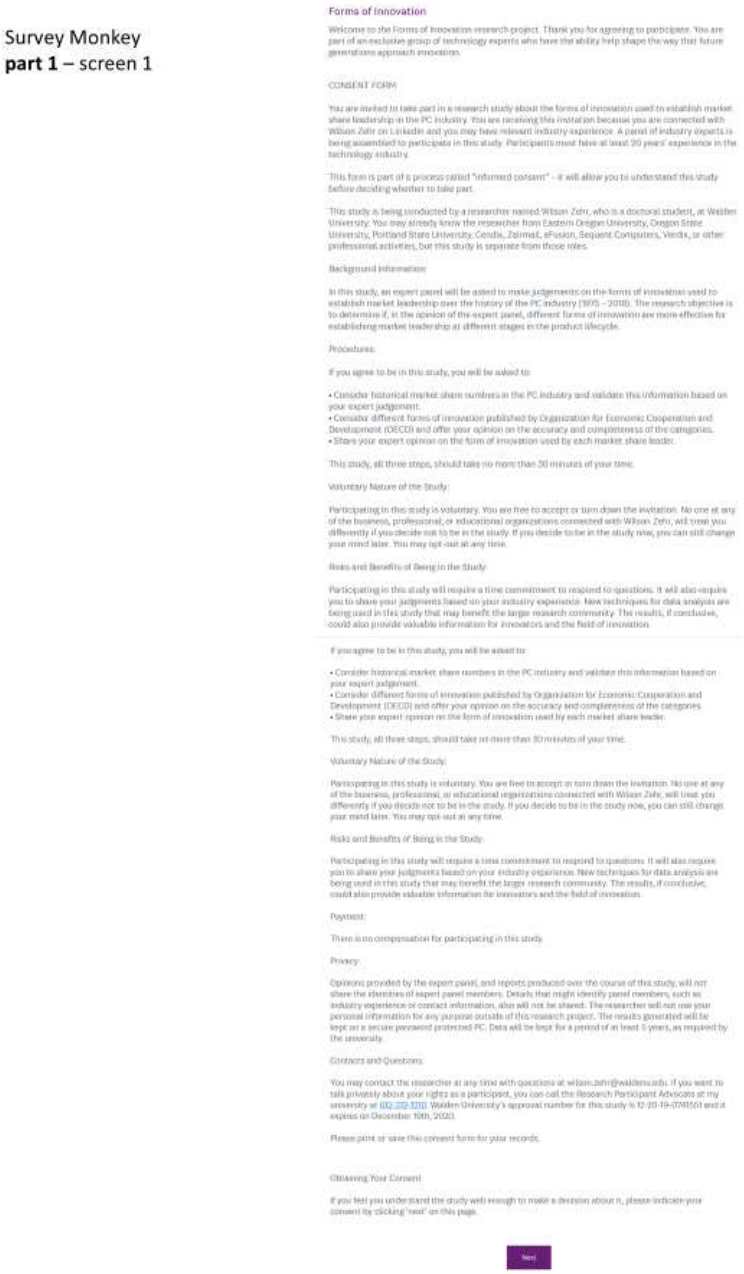
Group Results

Thank You for Participating! Your responses will help future generations of innovators...

You will receive a copy of these results in e-mail and a copy of the complete study will be sent to you when it is available. Please send an e-mail to wzehr@eou.com with any questions.

Appendix B: e-Delphi Actual Screens

Survey Monkey
part 1 – screen 1



Forms of Innovation

Welcome to the Forms of Innovation research project. Thank you for agreeing to participate. You are part of an exclusive group of technology experts who have the ability help shape the way that future generations approach innovation.

CONSENT FORM

You are invited to take part in a research study about the forms of innovation used to establish market share leadership in the PC industry. You are receiving this invitation because you are connected with Wilson Zehr on LinkedIn and you may have relevant industry experience. A panel of industry experts is being assembled to participate in this study. Participants must have at least 20 years' experience in the technology industry.

This form is part of a process called "informed consent" - it will allow you to understand this study before deciding whether to take part.

This study is being conducted by a researcher named Wilson Zehr, who is a doctoral student, at Walden University. You may already know the researcher from Eastern Oregon University, Oregon State University, Portland State University, Ceridix, Zalimad, eFusion, Sequent Computers, Verdix, or other professional activities, but this study is separate from those roles.

Background Information:

In this study, an expert panel will be asked to make judgements on the forms of innovation used to establish market leadership over the history of the PC industry (1975 - 2010). The research objective is to determine if, in the opinion of the expert panel, different forms of innovation are more effective for establishing market leadership at different stages in the product lifecycle.

Procedures:

If you agree to be in this study, you will be asked to:

• Consider historical market share numbers in the PC industry and validate this information based on your expert judgement.
• Consider different forms of innovation published by Organization for Economic Cooperation and Development (OECD) and offer your opinion on the accuracy and completeness of the categories.
• Share your expert opinion on the form of innovation used by each market share leader.

This study, all three steps, should take no more than 30 minutes of your time.

Voluntary Nature of the Study:

Participating in this study is voluntary. You are free to accept or turn down the invitation. No one at any of the business, professional, or educational organizations connected with Wilson Zehr, will treat you differently if you decide not to be in the study. If you decide to be in the study now, you can still change your mind later. You may opt-out at any time.

Risks and Benefits of Being in the Study:

Participating in this study will require a time commitment to respond to questions. It will also require you to share your judgments based on your industry experience. New techniques for data analysis are being used in this study that may benefit the larger research community. The results, if conclusive, could also provide valuable information for innovators and the field of innovation.

If you agree to be in this study, you will be asked to:

• Consider historical market share numbers in the PC industry and validate this information based on your expert judgement.
• Consider different forms of innovation published by Organization for Economic Cooperation and Development (OECD) and offer your opinion on the accuracy and completeness of the categories.
• Share your expert opinion on the form of innovation used by each market share leader.

This study, all three steps, should take no more than 30 minutes of your time.

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Risks and Benefits of Being in the Study:

Participating in this study will require a time commitment to respond to questions. It will also require you to share your judgments based on your industry experience. New techniques for data analysis are being used in this study that may benefit the larger research community. The results, if conclusive, could also provide valuable information for innovators and the field of innovation.

Payment:

There is no compensation for participating in this study.

Privacy:

Opinions provided by the expert panel, and reports produced over the course of this study, will not share the identities of expert panel members. Details that might identify panel members, such as industry experience or contact information, also will not be shared. The researcher will not use your personal information for any purpose outside of this research project. The results generated will be kept on a secure password protected PC. Data will be kept for a period of at least 5 years, as required by the university.

Contacts and Questions:

You may contact the researcher at any time with questions at wilson.zehr@waldenu.edu. If you want to talk privately about your rights as a participant, you can call the Research Participant Advocate at my university at 612-312-1210. Walden University's approval number for this study is 12-20-19-0701501 and it expires on December 19th, 2020.

Please print or save this consent form for your records.

Obtaining Your Consent

If you feel you understand the study well enough to make a decision about it, please indicate your consent by clicking "next" on this page.

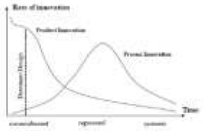
Next

Survey Monkey
part 1 – screen 2

Background:

Innovation has been responsible for 80% of US economic growth since World War II (Atkinson, 2011). Innovation can lead to significant new products that expand existing markets or create completely new ones (Christensen, 1997; Christensen & Raynor, 2003). The top five publicly traded U.S. firms in terms of market capitalization are Apple, Alphabet (Google), Microsoft, Amazon, and Facebook (Desjardins, 2018; Kiesnoski, 2017). In 2018 Apple became the first company in history to break $1 trillion in market capitalization (Galinas, 2018). In 2019 Microsoft crossed the $1 trillion market capitalization threshold to become the most valuable company in the world (Kilgore, 2019). These five companies also represent the most valuable global brands (Frangoul, 2017). Of these top companies only two, Microsoft which was started in 1975, and Apple which was started in 1976, existed before 1994. Amazon was started in 1994, Alphabet (Google) was started in 1998, and Facebook was started in 2004. These companies were all propelled to the top by significant innovations that they created and brought to market.

The Organization for Economic Cooperation and Development (OECD), the foremost international authority on measuring innovation (OECD, 2018), officially recognized only technological product and process innovation from 1997 to 2005 (OECD, 1997). Utterback (1994), building on Utterback and Abernathy (1975), showed that firms focus on product innovation early in the lifecycle, and then shift focus to process innovation as markets mature. This body of research, which guides innovators and researchers, is generally referred to as the A-U model (Akinke, 2013). In the third edition of the Oslo manual, the OECD officially recognized product, process, marketing, and organizational innovation (OECD, 2005). The absence of non-technological forms of innovation, in foundational tools such as the A-U model, exposes a research gap.



In this study you will be asked to (a) validate the market share leaders based on public information, (b) establish the forms of innovation that will be considered, and (c) identify the form of innovation that helped establish market leadership over the 40-year (1976 – 2016) history of the PC industry. The goal is to identify patterns (if any) in the focus of innovation activities by the market leaders over the entire lifecycle to this point.

References

Prev Next

Survey Monkey
part 1 – screen 3

Instructions:

Please answer the questions on the screens that follow. You can enter comments (if any) in the space that is provided. These comments will be shared with other participants only if required to establish a consensus. Comments are anonymous and no names will be shared. Participants will each be able to see the results and will receive a copy of the finished research report.

Please make sure to rank every market share leader with respect to all the forms of innovation presented – use your experience, articles, or other research materials to make your choices.

Prev Next

Survey Monkey
part 1 – screen 4

PC Industry Market Share Leaders 1975 to 2019
U.S. units sold

1975 -76	1977-80	1981-82	1983-90	1986; 1989; 1991	1992-93	1994-95	1996-99	2000-08	2009-19	2013-19
Altair	AST/Tandy	Apple	IBM	Commodore	Apple	Packard Bell (NEC)	Compaq	Dell	HP	Lenovo*

*worldwide

Market share data. Numbers are based on results reported publicly by International Data Corporation (IDC), Gartner Group, and Ars Technica.

Do these numbers appear accurate to you?

- Yes
- No

Please share concerns (if any) in the box below:

Frequently Asked Questions (FAQ):
Who is the Organization for Economic Cooperation and Development (OECD)?
What is the OECD Oslo Manual?
Why the 3rd edition?

Prev Next

Survey Monkey
part 1 – screen 5

Organization for Economic Cooperation and Development (OECD)
Oslo Manual, 3rd edition (9005)

A **product innovation** is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.

A **process innovation** is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.

A **marketing innovation** is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing.

An **organizational innovation** is the implementation of a new organizational method in the firm's business practices, workplace organization or external relations.

Note: in this framework, business model innovation, is composed of some combination of the other forms of innovation. Details of each innovation type can be found here

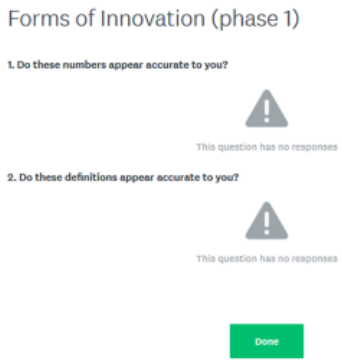
Do these definitions appear accurate to you?

- Yes
- No

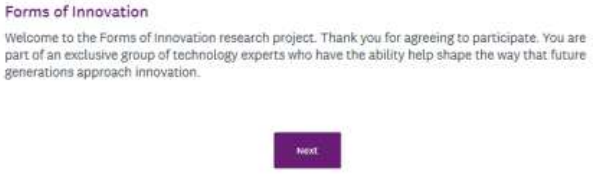
Please share concerns (if any) in the box below:

Prev Done

Survey Monkey
part 1 – screen 6



Survey Monkey
part 2 – screen 1



Survey Monkey
part 2 – screen 2

Instructions:

Please make sure to rank every market share leader with respect to all the forms of innovation presented - use your experience, articles, or other research materials to make your choices.

Participants will each be able to see the results and will receive a copy of the finished research report.

Prev Next

Survey Monkey
part 2 – screen 3

PC Industry Market Share Leaders 1975 to 2019
U.S. units sold

1975 -76	1977-80	1981-82	1983-90	1986; 1989; 1991	1992-93	1994-95	1996-99	2000-08	2009-19	2013-19
Altair	AST/Tandy	Apple	IBM	Commodore	Apple	Packard Bell (NEC)	Compaq	Dell	HP	Lenovo*

*hybridvide

Market share data. Numbers are based on results reported publicly by International Data Corporation (IDC), Gartner Group, and Ars Technica.

Please rate the importance of the form of innovation in establishing market leadership for **Altair in 1975**.

	not important								very important
Product innovation (changes in product produced)	○	○	○	○	○	○	○	○	○
Process innovation (changes in production process)	○	○	○	○	○	○	○	○	○
Marketing innovation (changes in marketing mix)	○	○	○	○	○	○	○	○	○
Organizational innovation (changes in structure / operation of organization)	○	○	○	○	○	○	○	○	○

What is your confidence level in these rankings?

	not confident								very confident
Confidence level	○	○	○	○	○	○	○	○	○

While a market leader, did the focus of innovation by this company change?

○ Yes

○ No

If yes, please describe:

Prev Next

Survey Monkey
part 2 – screen 4…screen 13

This pattern is repeated for each market share leader 1975 - 2019

PC Industry Market Share Leaders 1975 to 2019
U.S. units sold

1975-76	**1977-80**	1981-82	1983-90	1986; 1989; 1991	1992-93	1994-95	1996-99	2000-08	2009-19	2013-19
Altair	**AST/Tandy**	Apple	IBM	Commodore	Apple	Packard Bell (NEC)	Compaq	Dell	HP	Lenovo*

*worldwide

Market share data. Numbers are based on results reported publicly by International Data Corporation (IDC), Gartner Group, and Ars Technica.

Please rate the importance of the form of innovation in establishing market leadership for **AST/Tandy in 1977**.

	not important								very important
Product innovation (changes in product produced)	○	○	○	○	○	○	○	○	○
Process innovation (changes in production process)	○	○	○	○	○	○	○	○	○
Marketing innovation (changes in marketing mix)	○	○	○	○	○	○	○	○	○
Organizational innovation (changes in structure / operation of organization)	○	○	○	○	○	○	○	○	○

What is your confidence level in these rankings?

	not confident								very confident
Confidence level	○	○	○	○	○	○	○	○	○

While a market leader, did the focus of innovation by this company change?

○ Yes
○ No

If yes, please describe:

Prev Next

Survey Monkey
part 2 – screen 14

This screen will provide a summary of the results (when there is data).

The mathematical consensus will still need to be calculated in a separate step. That will be shared with participants in a summary document.

Forms of Innovation (phase 2)

1. Please rate the importance of the form of innovation in establishing market leadership for Altair in 1975:

This question has no responses

2. What is your confidence level in these rankings?

This question has no responses

3. While a market leader, did the focus of innovation by this company change?

This question has no responses

4. Please rate the importance of the form of innovation in establishing market leadership for AST/Tandy in 1977:

This question has no responses

5. What is your confidence level in these rankings?

This question has no responses

6. While a market leader, did the focus of innovation by this company change?

This question has no responses

7. Please rate the importance of the form of innovation in establishing market leadership for Apple in 1981:

Pattern continues from 1 to 15 to assess expert panel confidence in result.

Appendix C: Market Share and Forms of Innovation Response Data

Altair

1975 - 1976

	Product	Process	Marketing	Organizational
Geometric Mean	7.60	3.15	3.90	2.25
Arithmatic Mean	7.83	3.79	4.88	3.17

$a_1 \rightarrow a_2$	$a_1 \rightarrow a_3$	$a_1 \rightarrow a_4$	$a_2 \rightarrow a_3$	$a_2 \rightarrow a_4$	$a_3 \rightarrow a_4$
4.45	3.71	5.36	-0.74	0.90	1.65

	a_1	a_2	a_3	a_4
a_1	1.00	5.45	4.71	6.36
a_2	0.18	1.00	0.57	1.90
a_3	0.21	1.74	1.00	2.65
a_4	0.16	0.53	0.38	1.00
sum	1.55	8.72	6.66	11.90

	X_1	X_2	X_3	X_4	mean	consistency
X_1	0.64	0.63	0.71	0.53	0.62	4.08
X_2	0.12	0.11	0.09	0.16	0.12	4.03
X_3	0.14	0.20	0.15	0.22	0.17	4.05
X_4	0.10	0.06	0.06	0.08	0.07	4.07
	1.00	1.00	1.00	1.00	CI	0.02
					RI	0.90
					CR	0.02

AST/Tandy

1977 - 1980

	Product	Process	Marketing	Organizational
Geometric Mean	6.78	4.45	5.99	2.68
Arithmatic Mean	6.96	4.83	6.26	3.43

$a_1 \rightarrow a_2$	$a_1 \rightarrow a_3$	$a_1 \rightarrow a_4$	$a_2 \rightarrow a_3$	$a_2 \rightarrow a_4$	$a_3 \rightarrow a_4$
2.34	0.80	4.11	-1.54	1.77	3.31

	a_1	a_2	a_3	a_4
a_1	1.00	3.34	1.80	5.11
a_2	0.30	1.00	0.39	2.77
a_3	0.56	2.54	1.00	4.31
a_4	0.20	0.36	0.23	1.00
sum	2.05	7.23	3.43	13.19

	X_1	X_2	X_3	X_4	mean	consistency
X_1	0.49	0.46	0.53	0.39	0.46	4.05
X_2	0.15	0.14	0.12	0.21	0.15	4.06
X_3	0.27	0.35	0.29	0.33	0.31	4.04
X_4	0.10	0.05	0.07	0.08	0.07	4.07
	1.00	1.00	1.00	1.00	CI	0.02
					RI	0.90
					CR	0.02

Apple

1981 - 1982

	Product	Process	Marketing	Organizational
Geometric Mean	8.26	4.50	6.91	3.76
Arithmatic Mean	8.35	5.22	7.39	4.65

$a_1 \to a_2$	$a_1 \to a_3$	$a_1 \to a_4$	$a_2 \to a_3$	$a_2 \to a_4$	$a_3 \to a_4$
3.76	1.34	4.50	-2.42	0.74	3.16

	a_1	a_2	a_3	a_4
a_1	1.00	4.76	2.34	5.50
a_2	0.21	1.00	0.29	1.74
a_3	0.43	3.42	1.00	4.16
a_4	0.18	0.58	0.24	1.00
sum	1.82	9.75	3.88	12.40

	X_1	X_2	X_3	X_4	mean	consistency
X_1	0.55	0.49	0.60	0.44	0.52	4.07
X_2	0.12	0.10	0.08	0.14	0.11	4.04
X_3	0.23	0.35	0.26	0.34	0.29	4.06
X_4	0.10	0.06	0.06	0.08	0.07	4.05
	1.00	1.00	1.00	1.00	CI	0.02
					RI	0.90
					CR	0.02

IBM

1983 - 1988, 1990

	Product	Process	Marketing	Organizational
Geometric Mean	6.15	5.53	6.15	5.29
Arithmatic Mean	6.57	6.04	6.57	5.96

$a_1 \to a_2$	$a_1 \to a_3$	$a_1 \to a_4$	$a_2 \to a_3$	$a_2 \to a_4$	$a_3 \to a_4$
0.62	0.00	0.87	-0.62	0.25	0.87

	a_1	a_2	a_3	a_4
a_1	1.00	1.62	1.00	1.87
a_2	0.62	1.00	0.62	1.25
a_3	1.00	1.62	1.00	1.87
a_4	0.54	0.80	0.54	1.00
sum	3.15	5.05	3.15	5.98

	X_1	X_2	X_3	X_4	mean	consistency
X_1	0.32	0.32	0.32	0.31	0.32	4.00
X_2	0.20	0.20	0.20	0.21	0.20	4.00
X_3	0.32	0.32	0.32	0.31	0.32	4.00
X_4	0.17	0.16	0.17	0.17	0.17	4.00
	1.00	1.00	1.00	1.00	CI	0.00
					RI	0.90
					CR	0.00

Commodore

1986, 1989, 1991

	Product	Process	Marketing	Organizational
Geometric Mean	6.18	4.49	5.17	3.69
Arithmatic Mean	6.47	4.89	5.68	4.37

$a_1 \rightarrow a_2$	$a_1 \rightarrow a_3$	$a_1 \rightarrow a_4$	$a_2 \rightarrow a_3$	$a_2 \rightarrow a_4$	$a_3 \rightarrow a_4$
1.70	1.01	2.50	-0.69	0.80	1.48

	a_1	a_2	a_3	a_4
a_1	1.00	2.70	2.01	3.50
a_2	0.37	1.00	0.59	1.80
a_3	0.50	1.69	1.00	2.48
a_4	0.29	0.56	0.40	1.00
sum	2.15	5.94	4.01	8.78

	X_1	X_2	X_3	X_4	mean	consistency
X_1	0.46	0.45	0.50	0.40	0.45	4.03
X_2	0.17	0.17	0.15	0.20	0.17	4.01
X_3	0.23	0.28	0.25	0.28	0.26	4.02
X_4	0.13	0.09	0.10	0.11	0.11	4.02
	1.00	1.00	1.00	1.00	CI	0.01
					RI	0.90
					CR	0.01

Apple

1992 - 1993

	Product	Process	Marketing	Organizational
Geometric Mean	7.57	5.00	7.08	4.63
Arithmatic Mean	7.85	5.60	7.40	5.20

$a_1 \rightarrow a_2$	$a_1 \rightarrow a_3$	$a_1 \rightarrow a_4$	$a_2 \rightarrow a_3$	$a_2 \rightarrow a_4$	$a_3 \rightarrow a_4$
2.57	0.49	2.94	-2.09	0.36	2.45

	a_1	a_2	a_3	a_4
a_1	1.00	3.57	1.49	3.94
a_2	0.28	1.00	0.32	1.36
a_3	0.67	3.09	1.00	3.45
a_4	0.25	0.73	0.29	1.00
sum	2.21	8.39	3.10	9.75

	X_1	X_2	X_3	X_4	mean	consistency
X_1	0.45	0.43	0.48	0.40	0.44	4.02
X_2	0.13	0.12	0.10	0.14	0.12	4.01
X_3	0.30	0.37	0.32	0.35	0.34	4.01
X_4	0.12	0.09	0.09	0.10	0.10	4.01
	1.00	1.00	1.00	1.00	CI	0.00
					RI	0.90
					CR	0.01

Packard Bell

1994 - 1995

	Product	Process	Marketing	Organizational
Geometric Mean	4.62	5.56	5.14	4.21
Arithmatic Mean	5.17	6.17	5.72	4.78

$a_1 \rightarrow a_2$	$a_1 \rightarrow a_3$	$a_1 \rightarrow a_4$	$a_2 \rightarrow a_3$	$a_2 \rightarrow a_4$	$a_3 \rightarrow a_4$
-0.94	-0.52	0.41	0.42	1.35	0.93

	a_1	a_2	a_3	a_4
a_1	1.00	0.51	0.66	1.41
a_2	1.94	1.00	1.42	2.35
a_3	1.52	0.70	1.00	1.93
a_4	0.71	0.43	0.52	1.00
sum	5.18	2.64	3.60	6.68

	X_1	X_2	X_3	X_4	mean	consistency
X_1	0.19	0.19	0.18	0.21	0.19	4.00
X_2	0.38	0.38	0.40	0.35	0.37	4.01
X_3	0.29	0.27	0.28	0.29	0.28	4.00
X_4	0.14	0.16	0.14	0.15	0.15	4.01
	1.00	1.00	1.00	1.00	CI	0.00
					RI	0.90
					CR	0.00

Compaq

1996 - 1999

	Product	Process	Marketing	Organizational
Geometric Mean	6.39	5.65	6.09	4.39
Arithmatic Mean	6.63	6.00	6.63	4.84

$a_1 \rightarrow a_2$	$a_1 \rightarrow a_3$	$a_1 \rightarrow a_4$	$a_2 \rightarrow a_3$	$a_2 \rightarrow a_4$	$a_3 \rightarrow a_4$
0.74	0.30	2.01	-0.44	1.26	1.70

	a_1	a_2	a_3	a_4
a_1	1.00	1.74	1.30	3.01
a_2	0.57	1.00	0.70	2.26
a_3	0.77	1.44	1.00	2.70
a_4	0.33	0.44	0.37	1.00
sum	2.67	4.62	3.37	8.97

	X_1	X_2	X_3	X_4	mean	consistency
X_1	0.37	0.38	0.39	0.34	0.37	4.01
X_2	0.21	0.22	0.21	0.25	0.22	4.01
X_3	0.29	0.31	0.30	0.30	0.30	4.00
X_4	0.12	0.10	0.11	0.11	0.11	4.01
	1.00	1.00	1.00	1.00	CI	0.00
					RI	0.90
					CR	0.00

Dell

2000 - 2008

	Product	Process	Marketing	Organizational
Geometric Mean	5.59	7.59	7.90	6.12
Arithmatic Mean	6.11	7.79	8.11	6.47

$a_1 \rightarrow a_2$	$a_1 \rightarrow a_3$	$a_1 \rightarrow a_4$	$a_2 \rightarrow a_3$	$a_2 \rightarrow a_4$	$a_3 \rightarrow a_4$
-1.99	-2.31	-0.53	-0.31	1.47	1.78

	a_1	a_2	a_3	a_4
a_1	1.00	0.33	0.30	0.65
a_2	2.99	1.00	0.76	2.47
a_3	3.31	1.31	1.00	2.78
a_4	1.53	0.41	0.36	1.00
sum	8.83	3.05	2.42	6.90

	X_1	X_2	X_3	X_4	mean	consistency
X_1	0.11	0.11	0.12	0.09	0.11	4.01
X_2	0.34	0.33	0.31	0.36	0.33	4.01
X_3	0.37	0.43	0.41	0.40	0.40	4.01
X_4	0.17	0.13	0.15	0.14	0.15	4.01
	1.00	1.00	1.00	1.00	CI	0.00
					RI	0.90
					CR	0.00

HP

2009 - 2019

	Product	Process	Marketing	Organizational
Geometric Mean	5.21	5.02	5.55	5.50
Arithmatic Mean	5.79	5.47	6.05	6.05

$a_1 \rightarrow a_2$	$a_1 \rightarrow a_3$	$a_1 \rightarrow a_4$	$a_2 \rightarrow a_3$	$a_2 \rightarrow a_4$	$a_3 \rightarrow a_4$
0.19	-0.34	-0.29	-0.53	-0.48	0.05

	a_1	a_2	a_3	a_4
a_1	1.00	1.19	0.75	0.78
a_2	0.84	1.00	0.65	0.67
a_3	1.34	1.53	1.00	1.05
a_4	1.29	1.48	0.95	1.00
sum	4.47	5.21	3.35	3.50

	X_1	X_2	X_3	X_4	mean	consistency
X_1	0.22	0.23	0.22	0.22	0.22	4.00
X_2	0.19	0.19	0.19	0.19	0.19	4.00
X_3	0.30	0.29	0.30	0.30	0.30	4.00
X_4	0.29	0.28	0.28	0.29	0.29	4.00
	1.00	1.00	1.00	1.00	CI	0.00
					RI	0.90
					CR	0.00

Lenovo

	Product	Process	Marketing	Organizational
Geometric Mean	5.56	5.37	6.47	4.85
Arithmatic Mean	5.95	6.05	6.79	5.26

$a_1 \rightarrow a_2$	$a_1 \rightarrow a_3$	$a_1 \rightarrow a_4$	$a_2 \rightarrow a_3$	$a_2 \rightarrow a_4$	$a_3 \rightarrow a_4$
0.19	-0.91	0.70	-1.10	0.51	1.62

	a_1	a_2	a_3	a_4
a_1	1.00	1.19	0.52	1.70
a_2	0.84	1.00	0.48	1.51
a_3	1.91	2.10	1.00	2.62
a_4	0.59	0.66	0.38	1.00
sum	4.34	4.96	2.38	6.83

	X_1	X_2	X_3	X_4	mean	consistency
X_1	0.23	0.24	0.22	0.25	0.23	4.00
X_2	0.19	0.20	0.20	0.22	0.20	4.00
X_3	0.44	0.42	0.42	0.38	0.42	4.01
X_4	0.14	0.13	0.16	0.15	0.14	4.01
	1.00	1.00	1.00	1.00	CI	0.00
					RI	0.90
					CR	0.00

Appendix D: U.S. PC Market Share Data Set (1975 – 2019)

U.S. PC Market Share

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Acer	-	-	-	-	-	-	-	-	-	-	-	-	-
Altair	100.0%	13.0%	6.1%	3.3%	-	-	-	-	-	-	-	-	-
Apple	-	-	0.4%	9.1%	21.0%	29.3%	41.0%	28.5%	20.0%	19.0%	18.0%	16.0%	14.0%
AST/Tandy	-	-	60.8%	49.6%	48.1%	37.6%	22.5%	10.1%	5.0%	4.0%	3.0%	2.5%	2.0%
Commodore	-	-	2.4%	9.9%	15.5%	15.8%	10.6%	3.6%	21.6%	32.4%	32.8%	33.2%	20.5%
Compaq	-	-	-	-	-	-	-	-	1.1%	2.5%	4.0%	5.8%	7.5%
Dell	-	-	-	-	-	-	-	-	-	0.0%	0.0%	0.3%	0.6%
Gateway	-	-	-	-	-	-	-	-	-	-	-	-	-
HP	-	-	-	-	-	0.7%	6.1%	4.6%	-	-	-	-	-
IBM/Lenovo	-	-	-	-	-	-	5.0%	22.2%	42.0%	39.5%	37.0%	32.5%	28.0%
Microsoft	-	-	-	-	-	-	-	-	-	-	-	-	-
Osborne	-	-	-	-	-	-	1.4%	8.2%	0.5%	-	-	-	-
Packard Bell (NEC)	-	-	-	-	-	-	-	-	-	-	-	-	-
Toshiba	-	-	-	-	-	-	-	-	-	-	-	-	-
Other	0.0%	87.0%	30.4%	28.1%	15.5%	16.7%	13.4%	22.9%	9.8%	2.6%	5.2%	9.8%	27.4%

U.S. PC Market Share

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Acer	-	-	-	-	-	-	-	-	4.5%	3.8%	3.0%	2.7%	2.3%
Altair	-	-	-	-	-	-	-	-	-	-	-	-	-
Apple	12.4%	10.7%	10.9%	13.8%	13.2%	13.4%	11.5%	10.6%	6.4%	4.1%	4.6%	3.2%	3.8%
AST/Tandy	1.9%	1.7%	1.8%	2.7%	2.8%	4.0%	3.5%	2.3%	2.4%	-	-	-	-
Commodore	17.5%	18.5%	13.6%	15.9%	9.6%	2.3%	0.3%	0.2%	-	-	-	-	-
Compaq	6.0%	4.4%	4.5%	4.1%	5.7%	9.4%	11.7%	10.8%	12.9%	16.0%	16.7%	16.2%	15.7%
Dell	0.9%	0.9%	1.0%	1.6%	3.7%	4.8%	4.2%	4.9%	6.8%	9.3%	13.2%	15.9%	18.5%
Gateway	-	0.2%	1.0%	2.5%	3.6%	4.3%	5.1%	5.1%	6.1%	7.1%	8.4%	8.6%	8.7%
HP	-	-	-	-	-	-	2.4%	3.8%	5.3%	6.6%	7.8%	6.4%	11.1%
IBM/Lenovo	22.5%	16.9%	16.1%	14.1%	11.7%	13.0%	8.7%	7.9%	8.3%	8.7%	8.2%	6.4%	5.4%
Microsoft	-	-	-	-	-	-	-	-	-	-	-	-	-
Osborne	-	-	-	-	-	-	-	-	-	-	-	-	-
Packard Bell (NEC)	-	3.3%	3.9%	4.7%	5.3%	6.4%	14.3%	14.4%	11.4%	8.8%	6.2%	5.2%	4.3%
Toshiba	-	-	-	-	-	-	-	-	-	-	1.4%	1.9%	2.3%
Other	39.0%	43.4%	47.2%	40.6%	44.4%	42.4%	38.3%	40.0%	35.9%	35.7%	30.5%	33.6%	27.9%

U.S. PC Market Share

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Acer	2.3%	1.9%	1.5%	1.1%	0.7%	1.4%	2.4%	6.0%	9.3%	12.1%	10.4%
Altair	-	-	-	-	-	-	-	-	-	-	-
Apple	3.8%	3.8%	3.7%	3.7%	3.6%	4.4%	5.2%	6.5%	7.9%	9.0%	10.5%
AST/Tandy	-	-	-	-	-	-	-	-	-	-	-
Commodore	-	-	-	-	-	-	-	-	-	-	-
Compaq	15.7%	-	-	-	-	-	-	-	-	-	-
Dell	18.5%	23.5%	28.5%	31.7%	34.9%	35.7%	32.8%	29.1%	29.4%	25.5%	23.4%
Gateway	8.7%	7.4%	6.0%	5.6%	5.1%	6.1%	-	-	-	-	-
HP	11.1%	18.4%	17.0%	18.8%	20.6%	20.4%	22.4%	24.8%	24.7%	25.0%	24.8%
IBM/Lenovo	5.4%	5.5%	5.6%	4.9%	4.3%	3.6%	4.2%	4.4%	4.1%	-	-
Microsoft	-	-	-	-	-	-	-	-	-	-	-
Osborne	-	-	-	-	-	-	-	-	-	-	-
Packard Bell (NEC)	4.3%	3.8%	-	-	-	-	-	-	-	-	-
Toshiba	2.3%	2.8%	2.8%	2.9%	3.1%	3.3%	3.8%	4.0%	4.6%	8.1%	8.8%
Other	27.9%	33.0%	34.9%	31.4%	27.7%	25.1%	29.2%	25.2%	20.0%	20.3%	22.1%

U.S. PC Market Share

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Acer	8%	0%	0%	0%	1%	1%	2%	3%	2%
Altair	-	-	-	-	-	-	-	-	-
Apple	11%	11%	11%	12%	13%	12%	13%	13%	13%
AST/Tandy	-	-	-	-	-	-	-	-	-
Commodore	-	-	-	-	-	-	-	-	-
Compaq	-	-	-	-	-	-	-	-	-
Dell	22%	21%	22%	24%	24%	25%	26%	27%	28%
Gateway	-	-	-	-	-	-	-	-	-
HP	26%	27%	25%	27%	28%	28%	31%	31%	30%
IBM/Lenovo	7%	8%	10%	11%	12%	14%	13%	15%	15%
Microsoft	-	-	-	-	-	-	2%	4%	4%
Osborne	-	-	-	-	-	-	-	-	-
Packard Bell (NEC)	-	-	-	-	-	-	-	-	-
Toshiba	9%	7%	7%	6%	5%	0%	-	-	-
Other	17%	26%	24%	20%	18%	19%	14%	8%	8%

Appendix E: Diffusion Curves for Home Users and Business