Combination and context: Exploring the process of technological innovation

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Table of Contents

List of Figures

List of Tables

Abstract

Innovation has long been described anecdotally as something that comes from individual genius. Successful innovators have often been heralded as a special class of people with rare talents and unique capacities to “think different” to deliver world changing innovation. This view is reflected in innovation literature, notably with the linear model, which more recently has been widely criticised on account of this almost exclusive focus on individual action and personality as the sole determinant of innovation success.

The technological innovation systems literature is a response, describing the achievement of any technological innovation as a result of a ‘system’ made up of things like individuals, resources, culture, intellectual property, working in complex ways to collectively achieve a specific technological innovation.

Whilst the theory of innovation systems is acknowledged as valuable, this thesis argues the systems theory is problematic as explanatory tool specifically for technological innovation. Primarily this is due to the strong boundary conditions required of systems theory- To recognise a system, there is a need to demarcate the system from its environment. These boundaries create a strong ‘inside’ - those individuals, technologies, resources identified to be within the system, working specifically on the technology, and ‘outside’-those technologies, people, resources and all other things viewed as external, not related or relevant. The limitation of technological innovation systems is that by necessity, research often becomes an almost exclusive investigation of those internal components as the source of innovation, leaving the wider environment largely ignored.

In contrast to this, other important innovation theory, including viewing innovation as a ‘recombination’ process, and significantly the recent theory of ‘technological exaptation’ suggest that this wider environment ignored by technological innovation system theory is potentially critically important to the achievement of technological innovation itself. The theories of combination and exaptation suggest that it is precisely things in the environment- the events, technologies or people that the technological innovation systems theory often exclude from analysis, that are important sources of innovation.

Abstract

The broad environment for a specific technological innovation is the focus of this research. Rather than use the term environment though, this research uses the expression of 'lifeworld' to describe the concept environment, with justification for this terminology offered in the thesis. This research then explores how lifeworld conditions change over time, and how these conditions impact the performance of those attempting to create a specific technological innovation. In doing so, the research uses the lifeworld concept to further explore and articulate innovation theories of combination, exaptation, uncertainty and accumulation.

These issues were explored with an in-depth single qualitative case study of portable digital music players. The case utilised extensive archival and secondary data (over 4,000 articles) as well as primary interviews with expert protagonists (23 hours of interview data). This resulted in a detailed chronology of events for the development of digital music players over an extended time (60+ years). This event history was then used to explore the lifeworld concept, combination, exaptation, uncertainty and accumulation.

The study finds that the lifeworld, representing the wider environment, is critical to the creation of technology as well as the achievement of innovation: Portable digital music player innovation did not emerge only from a designated system, or individuals working on portable digital music player technology, but instead, often new events would spring from wider sources in the lifeworld, from domains previously unrelated to the specific pursuit of portable digital music player innovation. The lifeworld appeared an important tool to capture this detail, with recognition those working on the technology were often constrained or enabled by the wider conditions of the lifeworld in which the where placed. As the lifeworld changed, so too did the performance of those seeking to achieve portable digital music technology innovation. This was further expressed by Jon Rubinstein who described Apple's method for creating the iPod as principally one of combination, drawing quickly from common available conditions and technologies.

With these insights, the study provides a number of theoretical contributions, ranging from refining the theories of technological exaptation and combination, exploring the trajectory of the lifeworld and the stages of a development of a technological innovation, as well as recognition of the role of uncertainty and accumulation that makes possible technological innovation at one time and not another. From a practical perspective, the study offers a range of insights for individuals in respect to innovation timing, and how to look beyond ideas for technological innovation but instead to look for conditions that make technological innovation impossible at one time and likely at another.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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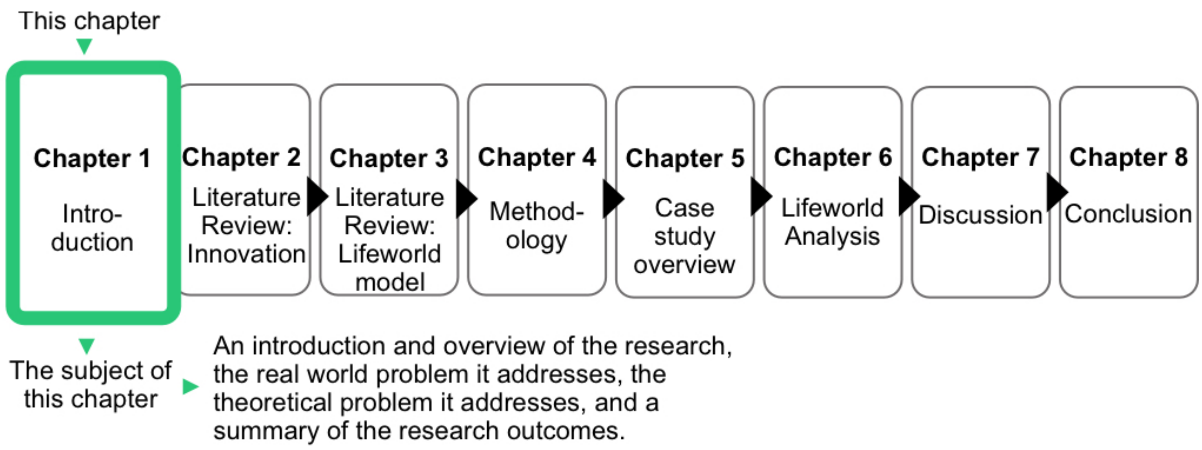
Mum, thanks for everything. You are a genius who gave it all to Nics and I. Nics, you are just like mum and are the most determined person I know, something you have proven over and over. Thanks for everything with the thesis and everything else. And thanks to Tanya. You are smart, generous, thoughtful, understanding, funny, and I am who I am because of you.

Chapter 1

Introduction



1.0 Introduction

Today, innovation is a driving force in business and society (Fagerberg, Fosaas & Sapprasert, 2012, p. 1). Innovation is no longer of speculative relevance to individuals, companies and economies, and its development is no longer left to chance by entrepreneurs, managers, and governments (Fagerberg & Verspagen, 2006, 2009). Technological innovation particularly is viewed as both a major opportunity and threat for individual companies and entrepreneurs – the creator and destroyer of industries. However, our understanding of innovation is complicated. Despite increasing recognition, its complex nature has made it a particularly difficult research phenomenon (Fagerberg & Verspagen, 2006, 2009). There are many theories of innovation, with a literature both complicated and messy, and overlapping across individual theories and theoretical domains (Godin, 2015). This research will leave many of these wider issues of innovation theory aside. Instead, this research will focus on technological innovation and explore a specific real world problem for entrepreneurs and investors, as well as a specific set of issues in theory.

This research explores the role of the "lifeworld" in the achievement of a particular technological innovation: How the context and environment available at any given time constrains and enables the capacity of those within it to create a particular technological innovation, and how this environment changes over time to make a once impossible technological innovation more likely. This research is process research using the methodology of a single in-depth case study: Portable digital music players, known colloquially as MP3 players. As part of this case study, wider events recognised as "digital music" are also explored.

The rest of this chapter will provide an overview of the study, documenting the detail of methodology, research process, findings, and implications, and offer a road map for the rest of the thesis. But it will begin more specifically, with a description of the focus of this research both as a practical problem from the case and as a theoretical problem from the technological innovation literature, culminating with the presentation of the four specific research questions of this study.

1.1 Practical problem focus

Kane Kramer had the idea for the first digital music player in 1979. He created drawings of his music player, established a company in the UK, and registered patents on parts of his design. But, after a few years of toil, the company failed, and Kramer never released a functioning product.

In 1995, 15 years later, researchers at NEC announced a working prototype of a portable digital music player using the newly developed flash memory. This 32 MB memory prototype had capacity for approximately eight songs, with the memory costing US$2,000 (Woudenberg, 1995). Acknowledging the prohibitive cost of the prototype, NEC said they would watch development of the technology closely, but they were never cited in the portable digital music player market again.

In 1997, Nathan Schullhof led a company that created an internet-connectable prototype music player called the Listen Up. He demonstrated it at the Consumer Electronics Show in 1997, announcing it with a projected retail price of US$299. It received an innovation award at the event and recognition in the press as a "big innovation in internet appliances" (Chiefet, 1997). Despite the recognition – and his company called Audio Highway listing on the stock exchange – two years later, Schullhof and the company failed.

In 1998, new players were released to the public for the first time. The Saehan MPMan and the Diamond Rio, both 32 MB flash players, retailed for between US$299 and $399. They were soon followed by a wave of entrants, with companies like Creative, Sony, Intel, and Samsung among others all offering similar portable digital music players between 1999 and 2001. Some of these companies achieved temporary success, but most of them ultimately failed. At the same time, other events like mp3.com, Napster, and Kazaa thrust digital music into a dramatic public spotlight, making digital music downloading a worldwide technological and cultural curiosity. Despite the intrigue and the occasional brief glimpse of success, these companies ultimately failed too.

In 2001, Apple released iTunes and the iPod, and in a few years became a worldwide consumer phenomenon. The potential of digital music and the portable digital music player that so many entrepreneurs had previously forecast and grasped at appeared to materialise all at once with the iPod, and almost the entire pool of success went to one company – Apple. By this stage, many high-profile entrepreneurs, recording industry figures, independent journalists, and others had all promoted, forecast, invested in, and pursued a digital music future, yet for all of them innovation remained elusive. For Apple the outcome was entirely different. They entered the market with a very short R&D lead time and very quickly achieved what no other company had: A revolution in the music industry and in music listening for consumers.

When reaching this juncture in describing a successful innovation, often the default is to extol the virtues of the successful protagonist. In this case, it would retrace the story of iPod as the story of Steve Jobs himself, presenting his personality as the source of innovation. For example, how Jobs sitting in on a calligraphy course at college later resulted in Apple's focus on design (Rosoff, 2016), or how Jobs' preference for the simple elegance of black turtleneck jumpers (Issaccson, 2011) manifest in the characteristics of the iPod, with its chic elegance a feature. This type of analysis suggests a rare capacity for startling innovation was hardwired into Jobs, and that achievements like the Macintosh, the iMac, and iPod all tumbled out as proof of this ready made genius.

The argument that the iPod is an outcome of genius is is hard to refute because the success of the iPod is not circumstantial but historically absolute: The iPod was a staggeringly dramatic success, and by obvious implication Steve Jobs was the most high- profile, tangible source of its genesis. But if Apple's achievements are viewed in the context of the long line of preceding failed entrepreneurs and companies, the simple assignment of the iPod to Jobs' unique genius without regard to the effort of others appears potentially disproportionate. Below the surface of the iPod there were thousands of people pursuing these ideas prior to Apple, often with incredibly similar insights and incredibly similar product features, often offered to the market first, but that ultimately, somehow, became hallmark achievements of Apple.

This issue becomes more intriguing the deeper this context of the iPod is explored. There were over a hundred portable music players already available in the market prior to Apple releasing the iPod, with many of them having individual features similar to the iPod (although no competitor had the entire feature set), and with the iPod relying on similar if not identical common technologies (steel, glass, electricity, digital music, the internet, system-on-a-chip computing) that Apple didn't create or uniquely control.

Additionally, many of the specific components of the iPod were off-the-shelf products from external suppliers. The iPod's hard drive (Toshiba), battery (Sony), AD converter (Wolfson), flash components (Sharp), and operating middleware software (Pixo) all came from external sources, where Apple either purchased the components from these suppliers or purchased these companies themselves. For example, in 2000 Apple purchased SoundJam (a music library software), then adjusted and improved it and released it as iTunes in 2001. In 2006, during a court case against burst.com, Apple's lawyers flew Kane Kramer out to California as a defence witness to describe how the iPod utilised similar ideas to Kramer's drawings and lapsed patents from 1979.

Even some of the most distinctive features of the iPod can be described as ideas influenced by existing products. For example, in conceiving the iPod scroll wheel, Apple acknowledged that it imitated the scroll wheel design of an existing Bang and Olufsen BeoCom telephone, and the iconic white exterior of the iPod was inspired from a transistor radio design from Dieter Rams released in 1958. Below the surface, it seems as though those things external to Apple, which they did not initiate and were generally available to everyone, were very important to the unique achievements of the iPod.

How did Apple achieve a revolutionary outcome when other entrepreneurs, companies, and journalists that claimed to be working on many of the same ideas utterly and unambiguously failed? What role did they play in the achievement of iPod? How did these people, events, and technologies contribute to the iPod? More specifically, did they need to happen prior to the iPod to make it possible?

These issues are the focus of this research which will investigate the success of the iPod not by focusing on the characteristics of Steve Jobs but, instead, by exploring this surrounding activity of portable digital music players. Were there particular conditions that made dramatic innovation in portable digital music players more likely for Apple compared others? And if so, how did Apple recognise, contribute, and then uniquely capitalise on these conditions when most other entrepreneurs failed?

1.2 Theoretical focus

Models of technological innovation and evolution reflect the expression that opportunity for a particular innovation is not evenly distributed. Innovation lifecycle models describe that technologies have long development processes (Dosi, 1982; Lispey, Carlaw & Bekar, 2005, location 1573; Nelson & Winter, 1977; Perez, 1983, 2002, 2004, 2010; Schumpeter, 1942, location 1837). Successful technologies emerge first as invention, proceed through development, and eventually transform into innovation (Garud, Tuertscher & Van de Ven, 2013, p. 777). This process takes time, to the extent that technological innovation lifecycle theory often describes this process in a number of distinct phases. Summarising these phases in popular lifecycle models (Anderson & Tushman, 1990; Dosi, 1982; Nelson & Winter 1982; Ogburn, 1950; Perez, 2010; Suárez, 2004; Usher, 1954; Utterback, 1978), the following appears to be the development process of a technology:

- Gestation of prior technologies occurs in the environment.
- At some point, the technologies offer conditions that lead to the invention of a new technology.
- This new technology is initiated as adolescent in performance but spurs a large volume of new entrants sensing potential for dramatic innovation.
- The large volume of entrants offer products as variations on the initial design. These reveal preferences and problems, but despite momentary glimpses of success, innovation proves elusive.
- At some point, a new product is released that becomes widely accepted by customers and becomes recognised as the dominant design and defining product of the category.
- This results in a large shakeout as competitors leave the market, and there emerges an oligopoly structure where the creator of the successful design will capture the majority of value for the entire market.

This lifecycle is credible (Garud et al. 2013), with a significant amount of empirical support (Stubbart & Knight, 2006, p. 86). These models suggest a reliable and predictable path of development to a particular technology, with the implication that there will exist only a brief moment where innovation is possible, capitalised on by a single victor to close off opportunity for all others.

Despite the empirical strength of these models, they do have current limitations. First, many of them offer representation of process (Checkland, 1981; Checkland & Scholes, 1990), describing process by way of markers of change, rather than mechanisms. Firm entry and exit rates at certain times in development, for example, appear a strong empirical marker of the process (Agarwal & Gort, 1996; Horvath, Schivardi & Woywode, 2001; Jovanovic & MacDonald, 1994; Klepper, 1996; Klepper & Miller, 1995). Whilst this is useful, it doesn't particularly address why these events emerge at certain times and whether there are more fundamental mechanisms that cause these outcomes.

A second criticism is one levelled at most linear innovation models (Freeman, 1991a, 1996; Kline & Rosenberg, 1986; Martin, 2012; Mowery & Rosenberg, 1979; Perez, 2010; Rosenberg, 1994), as well as recently emerging in the technological innovation system literature (Smith, Voß & Grin, 2010, p. 438; Tigabu, Berkhout & van Beukering, 2015, p. 1). These models tend to isolate the technology in focus from its wider environment, viewing and explaining progress as one generated by the effort of those working on the technology, as opposed to the wider external context in which it is placed. This issue is the focus of this research.

For many lifecycle models the wider environment is recognised sporadically, most often as the catalyst for initial conditions to spark invention (such as Usher's description of "setting of the stage" (1954)). But after this, in later phases, the role of the wider environment becomes murky, and, instead, description shifts towards the actions of individual protagonists. Whilst there is continuing strong acknowledgement of the environment (e.g., Dosi, 1988; Nelson & Winter, 1982) in the process of developing a particular technology, what specifically comes from the environment, and how and when, is not well described.

In alternative innovation theory, the conditions of the environment outside of the technology are noted to be important. Specifically, a renewed interest in the importance of innovation as combination (Arthur, 2009; Garud et al., 2013; Van de Ven, Garud & Venkataraman, 1999, location 185), along with the theory of exaptation (Adner & Levinthal, 2002; Cattani, 2006; Gould & Vrba, 1982; Levinthal, 1998), both suggest that rather than innovation being achieved exclusively by effort within the domain, drawing things from the environment at certain times can be a strong determinant of development and ultimately innovation. Exaptation particularly identifies that utilising existing technologies and *transferring* them to new uses for which they were previously not intended can create dramatic innovation without long development processes characterised by innovation lifecycle models (Adner & Levinthal, 2002, Cattani, 2006; Levinthal, 1998). This places emphasis on the general context outside of those working specifically on the technology as the source of dramatic advance for the technology itself.

The environment in which an idea for a technology is conceived is important, and beyond technological components emerging from exaptation, there are non-technological conditions that impact the achievement of a particular innovation. Other innovation theory acknowledges that at any given time there exists a broad frontier of socioeconomic and cultural influences, consumer preferences and familiarities, industry alignments, and relationships that all interact to present complex conditions that impact the value of a particular technology and its performance, as well as its likelihood of innovation (Bijker, 1997; Geels, 2005; Hughes, 1983; Unruh, 2000). In this way, the environment again is important – the value of a particular technology is not innate but relative to how it is perceived by the environment, where this environment may at times be particularly hostile to it, preconfigured with preference to another technology. How this environment changes, and how this presents difference in the potential of the same technology to achieve innovation at different times appears important. It also, as a consequence, ratchets up the difficulty of achieving innovation beyond what is controlled by those with ideas.

Without refinement of the role of the environment through the innovation lifecycle, there is a conflict between current innovation lifecycle models and theories of exaptation and combination. Currently, innovation lifecycle models present innovation as an outcome of a graduating and predictable series of phases largely driven by the internal development of a technology. Exaptation, in contrast, suggests that drawing existing technologies from the external environment and applying them to a new purpose can create radical innovation quickly, without this development process. With recognition of this conflict and the broader importance of the role of the environment, the environment surrounding a particular technology is the focus of this research, summarised as follows:

> Recognising that ideas for technology are dependent upon more than themselves for innovation, this research explores the role of the environment surrounding a technology, how the environment changes, and how, with related concepts of combination and exaptation, changes in the environment can create differences in the likelihood of a particular technological innovation at different times.

In an attempt to investigate this concept of environment, an array of terms appears relevant. Most notably, the above has referred to the concept as environment so far, but other terms like "context" (Autio et al., 2014), "milieu" (Burns & Stalker, 1961; Cooke & Morgan, 1994), "system" (Bergek et al., 2008), "ecosystem" (Adner & Euchner, 2014; Autio & Thomas, 2013) are all useful. Whilst these terms are relevant they often have a particular connotation which does not entirely match the concept of environment being expressed here. The focus is on the complete surrounding context of a technology at any given time, which includes people, things, technologies, and objects not obviously relevant to the technology in focus. The terms above don't appear to capture the essence of this. Terms like "environment" or "ecosystem", for example, evoke strong biological ecology connotations, while “milieu” has cultural or geographic connotations, and “system” clearly identifiable components and boundaries.

The concept being explored here seems different to these, albeit with the possibility of shoehorning any one of these above terms to fit. Rather than do this, this research will describe the environment as the lifeworld surrounding a technology (Husserl, 1970). The lifeworld comes from Husserl, who used it to describe “a coherent universe of existing objects” (Husserl, 1970 p. 108); applied to this study, the lifeworld of a technology represents the universe of existing things surrounding the technology and the technological domain at any given time.

1.3 The research questions

Reflecting the above description of the lifeworld and the focus on its role in the development of a technology, the research questions for this thesis are:

1. How significant is the lifeworld to events and innovation in the case study?
2. How are combination and exaptation relevant in the development of innovation?
3. What is the relationship between the internal domain and the external lifeworld?
4. How do the dynamics of the lifeworld impact innovation?

1.4 Scope of the research

The scope of the research is specific, but the concept of the lifeworld is broad and is an attempt to research something inherently difficult: to model and describe how the things surrounding an idea for a technology (events, other technologies, individuals, etc.), not at times obviously relevant to it, can impact its capacity to achieve innovation. Adding to the complexity, the research also focuses on the importance of viewing this lifeworld as a process – how it changed over time and how this leads to different conditions that enable and constrain innovation. Despite this broad focus, the guiding scope here for events to be included are those relevant specifically to the achievement of technological innovation, with this study consistent with the broad scope of other prominent innovation lifecycle models (Klepper, 1996; Usher, 1954), except for an increased focus on this wider lifeworld. Whilst the concept of the wider lifeworld as the condition under which ideas for a technology are conceived, and attempts at innovation are made, is intrinsically ambiguous, it is this ambiguity that appears important to the concept itself, with reference that a too tightly defined scope can potentially miss important phenomena as the source of innovation.

More general scope issues for this research recognise its purpose: This research has been designed and presented exclusively as a thesis for submission for PhD. It has been constructed with all the usual limitations and constraints of this process.

1.4.1 **Research design**

This research will use this concept of lifeworld, representing the broad environment, to analyse the development of portable digital music player technology through its history, culminating in the success of the iPod. Providing more detail to the scope above, the figure below outlines the research design of this thesis.

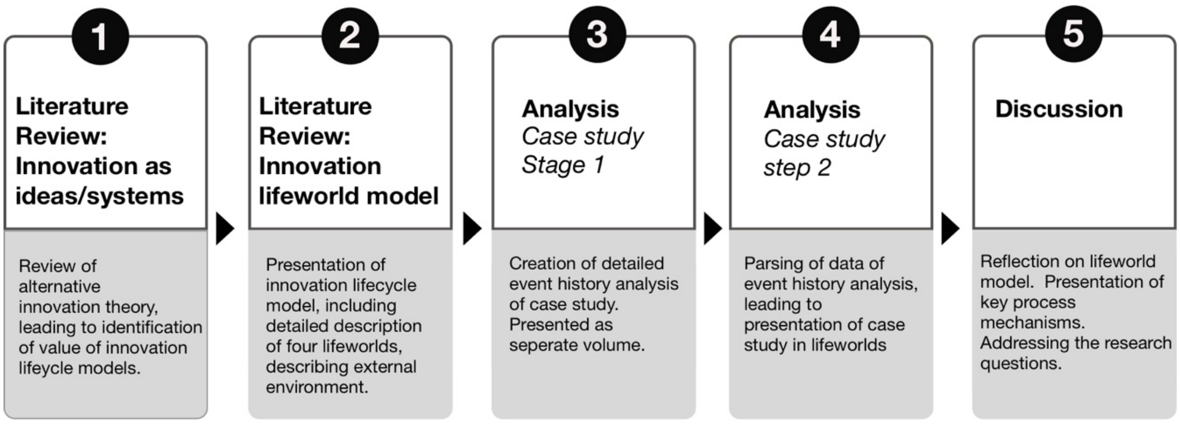


Figure 1.1 Research Design

Literature review: This thesis will present a review of the innovation literature, including a critique of the perspective of innovation as ideas, as well as technological innovation systems theory, leading to the identification of usefulness of innovation process theory, and in particular innovation lifecycle models. An identification of current limits, particularly with reference to external conditions is identified, framing the need for a new model. This literature review culminates in the presentation of the research questions provided earlier.

Technological lifeworld model: Chapter 3 presents an innovation lifeworld model, which explores and articulates the role of the environment through phases of prominent innovation lifecycle literature. This model presents four alternative lifeworlds, with a number of markers to each lifeworld, covering the innovation lifecycle of a particular technology. The four lifeworlds presented are prehistory, establishment, development, and innovation. This lifeworld model is not a new theoretical model but instead more generally organises existing technological innovation theory in a way that articulates the environment more clearly through existing stages of the innovation lifecycle.

Case study stage 1, event history analysis: A detailed event history analysis is created for the case study. This event history analysis is a chronology of events in the development of portable digital music players and the related domain of digital music. Data is utilised from extensive existing secondary sources, triangulated against expert opinion, as will be shortly described in more detail. This event history narrative describes events that occurred through the history of portable digital music player technology. This history is extensive and presented as a second volume; a shorter summary is offered in chapter 5 of this thesis.

Case study stage 2, lifeworld analysis: Events of the case are explored through the lens of the lifeworld model of chapter 3, exploring how the capacity to achieve innovation in portable digital music players differs over time. This analysis chapter presents the development of portable digital music player technology as occurring through four lifeworlds, where conditions in each lifeworld offered differing opportunities for innovation.

Discussion: The discussion chapter then answers the research questions, drawing from both previous chapters as well as salient theoretical concepts to articulate the role of the lifeworld in the achievement of innovation and offering further insight into the nature of exaptation and combination for technological innovation.

1.5 Methodology

This research presents a detailed longitudinal single in-depth case study of portable digital music players. Case study research is a dominant methodology in the field of innovation and technology studies, as well as specifically in innovation lifecycle research (Anderson & Tushman, 1990; Klepper & Simons, 1997). More than just a recent popular trend, longitudinal case studies have been the marker of some of the most seminal references in the innovation literature. Detailed case studies of steamboats (Gilfillan, 1935), radio (Maclaurin, 1950), electricity supply networks (Hughes, 1983), turbojet design (Constant, 1980), typewriters (David, 1985), bicycles and bakelite (Bijker, 1997), disk drives (Christensen, 1997), and the innovation process at 3M (Van de Ven et al., 1999) are a sample of the research that has informed and shaped the innovation literature through the lens of specific detailed case studies. Case studies have also been utilised in innovation PhD research, with examples such as fibre optics (Cattani, 2004) and the rigid disk drive industry (Christensen, 1992) being the early training for later well-recognised innovation researchers.

Justification for the case of portable digital music players

Digital music and portable digital music players were responsible for some of the most stunning dramatic and transformational events in the recording industry's history. Wider than that, these events became a cultural phenomenon. Protagonists such as Shawn Fanning, from Napster, and Steve Jobs, from Apple, were featured on the cover of *Time* magazine. Entrepreneurs such as Michael Robertson of mp3.com made fortunes, and others such as Sony lost them. Along with this, there were lawsuits and senate inquiries, and, for a brief time, digital music became a focus of mainstream news around the world.

Justifying his choice of study of steamboats in 1929, Obgurn identified that “Mechanization is one of the most striking and pervasive phenomena of our times” (Ogburn, 1929, p. 1). In 1983, Hughes justified his choice of study of electricity in similar concepts (Hughes, 1983, p. 1). Today, the internet, software, and computer hardware have similarly become high profile technologies responsible for some of the most dramatic stories of innovation of our time, across an increasing number of industries. Digital music was one of the first, and still perhaps one of the most, searing examples in what is now a long series of industries that have been reconfigured around these digital technologies. This case study offers relevance to all those industries who have similarly confronted these technologies since, as well as those who have yet to.

These events also marked the start of the transformation of Apple from the verge of bankruptcy in 1996 to the world’s largest company in 2011. The iPod initiated a sequence of success that later brought the iPhone, the iPad, and beyond. Offering insights about the innovation process at Apple during this time is to offer insights about innovation more generally. No other high-profile company in the world was as successful at innovation as Apple at this time.

Sources of data

The second reason the portable digital music player was selected as the case study was the availability of data. This research is innovation process research, where the focus is on describing and investigating the unfolding temporal pattern of events (Poole & Van de Ven, 2004; Van de Ven et al., 1999). The availability of data is a strength in this regard. As the case study’s development occurred after the emergence of the internet, and with tools such as the Internet Archive’s Wayback Machine, there exist large complete repositories of web articles that document developments in portable digital music players in real time as they occurred. The vast amount of web articles remains completely intact from their date of publishing, allowing for the creation of an event history narrative that chronicles developments as they occurred. The event history utilised over 4,000 of these articles to build a narrative that documents not only successes but also the environment, including the many failed avenues of advance that at various times prior to the iPod appeared as potential innovation.

This large volume of secondary data was triangulated with a range of primary interviews with expert protagonists. The interviews conducted for this study are listed in Table 1.1.

Table 1.1 Expert Interviews

Expert	**Position/Expertise**
Professor Karl Brandenburg	Creator of the MP3 file format, member of Secure Digital Media Initiative.
Hank Barry	CEO, Napster (peer-to-peer music trading software).
John Chowning	Creator of digital frequency modulation (FM) synthesis.
Thomas Dolby	Grammy Award-winning synthesiser artist, founder of multiple multimedia companies.
Julie Gordon	Copywriter for Apple’s iMac and iPod campaigns, creator of “Rip. Mix. Burn.” Headline.
Ken Hertz	Artist lawyer representing clients such as Alanis Morissette during this time. A member and attendee of the Secure Digital Music Initiation.
Andy Hill	IBM employee, and later founder of Multimedia Archive and Retrieval System (MARS).
Jeff Levy	University student prosecuted for copyright infringement due to online file sharing by the U.S. government.
Joanne and Tom Marino	Co-founders of online digital music news website www.webnoize.com, along with related yearly Webnoize conference.
Phil Morle	CTO, Kazaa (peer-to-peer music trading software).
Jeff Patterson	Co-founder of the Internet Underground Music Archive (IUMA), recognised as one of the first websites to download music on the internet and top 10 website worldwide for traffic during the mid-1990s.
Jon Potter	Founder of Digital Music Alliance (DiMA), a Washington-based political advocacy and lobbyist group for digital media entrepreneurs.
Kelli Richards	A&R at various major labels, PatroNet co-founder (the music distribution and fan interaction software created by high-profile Todd Rundgren in the early 1990s).

Expert	Position/Expertise
Jon Rubinstein	Vice president of engineering at Apple Computer. Recognised as critical to the creation of Apple products between 1997 and 2006, including the iMac, the iPod, and the iPhone. Leader of the initial iPod project, then subsequently head of iPod at Apple when it was established as a separate division in 2004. Left Apple in 2006, became CEO of Palm in 2008 until it was purchased by HP in 2010. Current board member of Amazon.com, Qualcomm, and co-CEO of Bridgewater, the largest hedge fund in the world.
Cary Sherman	Current chairman and CEO of the Recording Industry Association of America (RIAA), previously President of RIAA 2001–2011.
Zak Zalon	President Radio Free Virgin, Virgin Digital.

Case study boundaries – date range/focus

The event history analysis created from this data is very detailed and has both a large date range as well as breadth of focus. First, the date range is very broad. To capture detail in the prehistory lifeworld, some brief events are recorded from as far back as the 11th century (related to some imaginative science fiction descriptions of music players), then moves through the 20th century and onwards, with portable vinyl, cassette tape, and CD players all covered. But the majority of the detail of the narrative covers the major events of portable digital music players (from 1994 on). The end date boundary for this study is the end of 2007, when portable digital music players had stabilised around the iPod as the powerful dominant design.

Along with the length of focus, breadth of focus was also a characteristic of the event history narrative. In an attempt to capture wider lifeworld and avoid viewing the portable digital music player as an isolated trajectory, the event history narrative includes developments that occurred in wider fields of computing, consumer electronics, and the music recording industry, documenting changes in these fields over time. This means that whilst the focus is portable digital music players, the wider environment from which they emerged is recognised and events chronicled. This also means that the case study follows the twists and turns of developments as they occurred, rather than skips forward to the path of successful selection. It captures the uncertainty, multiple available pathways at any given point, momentum, shocks, and failures as they occurred.

The combination of both breadth and depth result in an expansive case study. Due to its large size it is presented in a separate volume. For the reader, please note:

It is not necessary to read this second volume completely or in detail. It is offered instead as support material for this thesis. Reference will be made to particular sections and events described in this second volume at times, and the reader is free to look these events up in the second volume for supplementary detail.

1.6 Research outcomes

Summarising the discussion chapter, the research questions were answered as follows:

1. *How significant is the lifeworld to events and innovation in the case study?*

The case study suggests that the external lifeworld was important to the development of portable digital music player technology. Many of the events that proved critical to the development of portable digital music players did not originate for the specific purpose of portable digital music players or from the preceding history of development of portable digital music players. Rather, often events, actors, and technologies that initiated dramatic events in the development of digital music players would have no previous relevance or recognition in the domain, instead emerging from their own trajectory of development more broadly occurring externally in the lifeworld.

The discussion chapter offers many examples of this: How, for example, events such as Napster (created by a university student), mp3.com (created by an entrepreneur watching popular search terms on the internet), Diamond Rio, MPMan (created by computer component companies), and the iPod (created by a PC company), emerged from the lifeworld. And in contrast, why previous events within the domain of portable music were not the source of innovation – Sony, for example, a powerful authority with the innovative legacy of the Walkman and Discman, was not the source of initiation of the portable digital music player market, with the first players emerging from computer component companies such as Diamond and Creative. Apple too is a notable example of the importance of the lifeworld – despite their dramatic achievements of innovation, prior to 2001 Apple was not particularly involved in digital music at all, and their engagement came as a surprise to those who were working on portable digital music players prior to their entry.

The discussion chapter discusses significance of the lifeworld as manifest in the ongoing state of uncertainty for all involved within the domain. For all actors, digital music and portable digital music players constantly developed under pervasive conditions of uncertainty, where new events would emerge not from existing understanding and narrative, but from externally-driven events. New events such as Napster, Kazaa, iTunes, and the iPod constantly emerged as "shocks" similar to those described by Van de Ven et al. (1999), where assessment and analysis did not account for these coming events prospectively. This promotes the relevance of the lifeworld, and that innovation was dependent on and in part driven by the lifeworld, rather than the previous history of the domain in focus. In further describing this concept, the discussion chapter identifies the theory of the time sequence trap (McMullen & Dimov, 2013) to be particularly useful to describe the role of the lifeworld in this regard.

2. *How are combination and exaptation relevant in the development of innovation?*

Consistent with the literature review, where a range of authors are noted to describe exaptation as something pervasive to radical innovation (Arthur, 2009, location 848; Constant, 1980, p. 2; Dew, Sarasvathy & Venkataraman, 2004, p. 70; Mokyr, 2002; Rosenberg, 1983, p. 75; Usher, 1954, p. 50), the case study quickly surfaces recombination and exaptation as common and important. Combination and exaptation were the 'mechanisms' by which individuals drew available things (technologies, concepts, people) from the lifeworld and connected them to the use of digital music or portable digital music players. There are many examples of exaptation and combination in the case study, but the most prominent example is the iPod itself, which is described in detail as a combination of available technologies, as well as a combination being specifically identified as the creation strategy employed by Apple, as identified by Jon Rubinstein, who initiated and led the iPod project at Apple (see case study section 10.5 as well as discussion chapter).

Beyond recognising the significance of combination and exaptation, the discussion chapter further explores a number of theoretical issues of both combination and exaptation that arise from the case study. These are summarised briefly as:

- There is current theoretical ambiguity regarding the difference between combination and exaptation in respect to technological innovation. The discussion chapter describes the concept of "multiple adjacent developments" to highlight this issue.
- There is opportunity to explore and refine the description of the significant role of incremental improvement in existing technologies that create windows of opportunity for exaptation and combination.
- The case study presents examples of exaptation that are not well described in theory – both exaptation of "concepts" rather than just technologies, and also examples of "failed" exaptation where exaptation did not lead to significant innovation, suggesting the need to further articulate combination and exaptation as mechanisms of creation rather than exclusively mechanisms of innovation.

These issues represent avenues of future research for the theories of both combination and exaptation, with both viewed as important concepts of technological innovation.

3. *What is the relationship between the internal domain and the external lifeworld?*

The third question explores the relationship between the internal domain and the external lifeworld. In an attempt not to isolate the external lifeworld, this question recognises that the domain itself also had a critical role in the achievement of innovation, and the lifeworld did not achieve all things exclusively. Whilst new events would often emerge from actors in the broader lifeworld, these new events too would interact with and draw from the domain.

The discussion chapter describes the interaction between the internal domain and the lifeworld in two concepts. First, recognising that the internal domain is dynamic and would respond to events, accumulation is explored as an important concept. Second, and extending this, the theory of “compressed algorithms” (Langley et al., 2013) is used to describe how those external to the lifeworld would draw from the accumulation that had occurred in the domain. Rather than having to create concepts from scratch, new events could build on previous experimentation. The discussion chapter extends this concept to describe how previous experimentation within the domain not only provided Apple with components to use that they didn’t need to reinvent (MP3, downloading, CD burning, etc.), but just as significantly previous portable music players released to the market offered Apple a set of problems to solve – the limitations (or reverse salient; Hughes, 1983) with existing players represented a compressed algorithm for Apple to address, such as the frustration at clicking through menus (leading to creation of the scroll wheel). Addressing problems and limitations in existing players became the source of much of Apple’s innovativeness.

4. *How do the dynamics of the lifeworld impact innovation?*

The final question is the major focus of much of both the model chapter as well as the analysis chapter, which explore the lifeworld as a process. It explores the dynamics of the lifeworld, and much like innovation lifecycle models that describe the development of a technology in a number of stages, similarly describes a number of lifeworlds through which a successful innovation must pass. The four lifeworlds are summarised as follows:

Prehistory lifeworld (pre–1994): The lifeworld does not offer the required technologies to create the technology in focus. Imaginative descriptions, such as Kane Kramer’s IXI player in 1979 or the Chippy Hoax emerged, but the failure of these ideas reflects that the lifeworld did not offer capacity to create the technology yet.

Establishment lifeworld (1994–1997): The first working portable digital music technologies were created as prototypes, most notably the NEC Silicon Audio player. This technology emerged from a range of sources but most notably relied on flash storage components from computer component manufacturers. The creation of the NEC Silicon Audio player relied upon the accumulation of technology in the lifeworld, and the achievement of particular thresholds of performance in existing technologies. For example, this player emerged after MPEG audio formats had been released, and after the trajectory of analog-to-digital converter technology had incrementally improved to make it fit in a portable device.

Development lifeworld (1997–2001): These years represent the most dramatic events in the trajectory of portable digital music players. The release of the Diamond Rio and the Saehan MPMan in 1997/1998 triggered a large volume of new entrants based around similar designs. Through this time, the technology was immature, but the trial and error revealed problems and preferences of the lifeworld, with many elements (support industries such as the recording industry, legal precedent) giving favour to the competing technology of compact disc. At the same time as these developments in portable digital music players, dramatic events were occurring more generally in the wider but related lifeworld of digital music. This time was characterised by a large amount of failure, but the accumulated failures both dynamically changed the domain and soon offered enabled conditions for dramatic innovation.

Innovation lifeworld (2001–2008). Apple released the iPod in 2001 and it was an initial success in comparison to other portables in the niche of the portable music player market. It would transfer this success to mainstream consumer markets worldwide by 2004, and by the end of this case study in 2007 was a worldwide consumer phenomenon. The lifeworld presented Apple with opportunities for innovation that were not available at previous times. The record labels that had previously resisted licensing, and had weathered turbulent conditions arising from peer-to-peer file sharing, now agreed to licenses with Apple to create the iTunes Music Store. Equally, the lifeworld offered new exaptation opportunities, with Apple utilising a new 1.8 inch prototype laptop hard drive from Toshiba to create the iPod. The availability of many of these conditions were outside the control of Apple, and the study finds that the enabling conditions of the lifeworld were a large contributor to Apple's success.

However, the study also finds that Apple didn't stumble upon these conditions. The iPod was not a simple extension of previous players, but instead a new unique combination where Apple drew deftly and diversely from the lifeworld, creating a product that offered superior value. Whilst the lifeworld offered conditions that made dramatic innovation possible in 2001 compared to previous or later times, the study also finds that Apple was unique in their ability to achieve this combination. Apple too appeared cognisant of these conditions and they were important criteria for Apple's entry into the digital music player market. From the primary interview for this research, Jon Rubinstein head of Apple's iPod division explains:

> *Anything we did at Apple we did in a heartbeat, right, we did with a sense of urgency, but we never did a product before it's time. Or we tried not to. So I*

> *think we waited a while till the technologies would really support the kind of product we wanted to build, so we waited quite a few months, until I found the 1.8 inch hard drive, and during that time displays had matured, battery technology had matured, so it was kind of just the right moment in time to go do it. (J. Rubinstein, personal communication, July 9, 2013)*

Overall the lifeworld was dynamic and offered varying capacity to achieve innovation at different times. Limitations of the lifeworld are discussed in the conclusion, but the description of lifeworld as a process had merit, and reflects how wider conditions at any given time offer either constraints or opportunities to achieve innovation, but as the lifeworld changes so too does the potential to achieve innovation.

1.7 Summary of contributions

This research presented the development of the technological innovation of portable digital music players as a process that occurs through a number of lifeworlds. It explored the conditions surrounding the technology as critical to the creation of the technology as well as the achievement of innovation. The theoretical and practical implications of this are discussed below.

Theoretical contributions

The lifeworld concept is useful when attempting to more clearly articulate the external conditions that impact the achievement of innovation, which appear important in the case study. More specifically, this research also offers a number of theoretical refinements and promotion of particular theories viewed as significant post the case study:

- The study offers a number of potential research directions in the theories of technological exaptation and combination.
- The study has highlighted the importance of a number of theories in the development of technological innovation, including accumulation, the time series trap, and the importance of incremental innovation.
- The study highlights the importance of viewing innovation as a process and as a temporal set of conditions that offer potential for innovation not possible at other times.

Practical considerations

The pursuit of innovation is a modern entrepreneurial and management imperative. This research suggests though, that a particular technological innovation is not possible at all times, but dependent on particular conditions. With this recognition, entrepreneurs and managers would do better to try to avoid attempts at radical innovation at certain times, looking to wider conditions rather than ideas for a particular technology themselves. If they move too early, when the wrong lifeworld exists, they may offer products that are difficult to create and that ultimately miss the mark for consumers, becoming entangled in a mix of potential and frustration. Later, under different lifeworld conditions, the same innovation may become achievable as entrepreneurs utilise a process of combination, drawing things from the lifeworld to create technologies that deliver value. There appears general acknowledgement of these ideas in common practitioner parlance, such as describing innovation as 'being in the right place at the right time', but, beneath this, practitioner short hand also reveals the lack of articulation in these ideas, defaulting to other expressions of timing as 'more art than science'. Whilst a complete understanding of innovation timing with predictive capacity for practitioners is perhaps an impossible quest, this study highlights and explores key mechanisms of timing, such as the lifeworld concept, exaptation and combination which all offer practitioners a deeper set of tools and a specific focus for thinking about innovation timing, which otherwise will remain a well acknowledged and ill described practitioner concept.

1.8 Thesis overview

This thesis is presented in eight chapters, with a references section, and a second volume as the event history analysis.

Chapter 1 Introduction and Context for the Research: This chapter has provided an overview of the research, including the problem statement, theoretical focus, case study, leading to the presentation of research questions, outcomes, and contributions.

Chapter 2 Literature Review: This provides the context for this study. Specifically, it compares alternative perspectives of innovation as both created by ideas and systems, identifying criticism of these perspectives. In response, it describes the value of innovation process theory, and, within this, more specifically the stream of innovation lifecycle models. Recognising the limits of these models, and acknowledging the emergence of new theories such as exaptation, the need to further explore the role of external factors is identified.

Chapter 3 Technology Lifeworld Models: Drawing from existing lifecycle models (Anderson & Tushman, 1990; Dosi, 1982; Nelson & Winter, 1982; Ogburn, 1950; Perez, 2002; Suárez, 2004; Usher, 1954; Utterback, 1978), a lifeworlds model is presented that covers four lifeworlds that a successful innovation must pass through.

Chapter 4 Research Methodology and Method: This study is recognised as process research and fits within process, ontological, and epistemological lenses. Specifically, the use of a phase-based description of innovation is recognised as a specific category of process research (Van de Ven & Poole, 1995). Process research is viewed as different from the traditional conception of variance research more common in the scientific method, with its own measures of reliability. After a discussion of these, this chapter moves on to discuss the details of the case study of portable digital music players. The case study has been constructed and presented in accordance with the guidelines of Yin (2013).

Chapter 5 Analysis: This chapter is a summary of the event history analysis presented in full in the second volume. This chapter summarises key events, offering a condensed overview and guide to the full event history analysis of the case study presented in the second volume.

Chapter 6 Analysis: The case study is presented using the innovation lifeworlds model. The four lifeworld are applied to the case, offering a lens through which to describe the development of portable digital music players.

Chapter 7 Discussion: The discussion chapter discusses the research questions in detail, highlighting the role of the lifeworld, as well as a range of theoretical issues emerging from the case study introduced above.

Chapter 8 Conclusion: This chapter summarises the research. Research limitations are identified, the contribution to both theoretical and practical knowledge are discussed, along with suggestions for further research.

Appendix – Event history analysis of Portable Digital Music Players: This is the detailed event history analysis of the case study. This is very detailed, and this is parsed to be presented as a lifecycle in chapter 5.

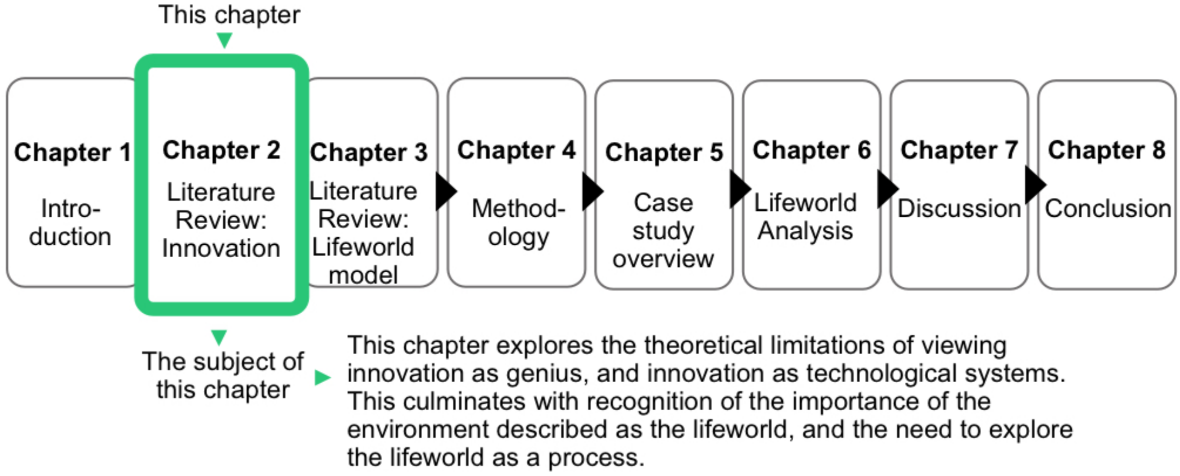
1.9 Chapter Summary

This introduction chapter provides the foundation of this thesis. The research is framed as a study of the environment impacting the creation and innovation of a particular technology, with this environment conceptualised as the lifeworld. The lifeworld is explored as a process, identifying how conditions change and how this makes a particular technological innovation possible at one time and not another.

This chapter describes the practical research problem and the theoretical problem at the heart of this research endeavour, an overview of the scope and research design, description and justification of the case study, a summary of the research outcomes and implications, and offers a synopsis of each chapter of the thesis. The next chapter, Literature Review, describes the relevant literature for this study, leading to the presentation of the research questions.

Chapter 2

Literature Review



2.0 Introduction

This chapter provides the context for this research which seeks to better process understanding of innovation, one that explores and better articulates the role of the external environment. This literature review leads to the presentation of both the research questions, and subsequently the lifeworld model of this research in the following chapter. The literature review first explains and critiques the theoretical and popular expression of innovation as an outcome of unique ideas and individuals. Then, recognising the value of viewing innovation as both an individual and collective act, the usefulness of innovation systems theory is described, with a focus on technological innovation systems. However, there are a number of identified weaknesses of systems theory, particularly in respect to dynamics and system boundaries, and a critique of technological innovation systems leads to the recognition of a need to view innovation from a process perspective. Reviewing a large amount of innovation process theory, and particularly focusing on innovation lifecycle models, there appears to be theoretical usefulness in exploring and more clearly articulating the role of the external environment throughout the lifecycle of technology, with recognition of its importance described via the competing theory of combination and exaptation. Articulating the role of environment throughout the lifecycle is the ambition of this research, leading to the presentation of research questions at the end of this chapter.

2.1 Innovation as ideas

For much of the 20th century, the predominant view of innovation in popular culture and theory was that it was an act of genius (Eysenck, 1979; Glynn, 1996; Lubinski, 2000). Innovation was recognised as "something that originates in the acts of the inventor" (Tuomi, 2002 p. 105), where great individuals relying only on wit and ingenuity cast from their minds the achievements of the world.

This notion of innovation as simply the achievements of great individuals remains a popular myth in culture (Silbey, 2014) – that a lone technical genius working in isolation (Hargadon, 2003), or a dogmatic entrepreneur pursuing a problem (Seabrook, 1993), will conceive of a revelatory idea as a eureka moment (Gaughan, 2010; Silbey, 2014). The individual then implementing the idea will rally against forces of existing industry, culture or science, experiencing moments of peril before eventually triumphing when the value of their idea, intact from the moment it was first conceived, is finally recognised and accepted (e.g., Landrum, 1993), shifting the entire culture forward. This narrative and variations of it persist in modern times, with Gates, Jobs and others marked as "The Innovators" (Isaacson, 2014), but this perspective has a long history. The obituary of Thomas Edison, published in 1931 in the *New York Times*, for example, describes Edison's achievements as his "inner self" brought forth to the world, suggesting, unintended or otherwise, that if it was possible to replay the tape of life, and Edison did not exist, neither would electricity:

> So it comes about that he was the last and greatest of a long line of experimenters who followed only the dictates of their inner selves and who were as willful and unrestrained as poets. With him the heroic age of invention probably ends. (Kaempffert, 1931, p. 22)

Innovation as the act of an individual conceiving of and refining ideas was also supported by some of the most prominent innovation theories of the 20th century. Both the linear model of innovation (Maclaurin, 1950, 1953) as well as the demand–pull theory of innovation (generally attributed to Schmookler (1966) as identified by Godin & Lane, 2013) frame innovation as individual genius. The linear model particularly, recognised as the cornerstone of science and innovation policies for the larger part of the 20th century (Godin, 2006; Freeman & Soete, 1997, location 6837; Mowery, 1983), places the individual conceiving of and then refining ideas as the basis of all innovation success. The popularity of this model was such that it led to perspectives like that of Harvard president James Bryant Conant, who claimed that the key to creating world changing innovation was “picking a man of genius, giving him money, and leaving him alone” (Chesbrough, Vanhaverbeke, & West, 2006, p. 5).

Retracing the formation of the linear model, Godin identifies its history as the cumulative work of a long list of researchers (Godin, 2015, 2011, 2008, 2006). The essence of all variations is a series of steps from individual idea generation through to successful innovation (e.g., pure science→ invention→ innovation→ finance→ diffusion). There have been attempts at theoretical addition, offering recognition of sophisticated feedback loops (Niosi, 1999) for example, or the effect of particular mechanisms like public funding (Hindle & Yencken, 2004), but, fundamentally, the linear model has remained consistent for 70 years now, underpinned by the recognition that conceiving ideas and then developing them creates innovation (Gelijns & Rosenberg, 1994; Godin, 2006).

More recently, there has emerged significant criticism of the linear model (Freeman, 1991b, 1996; Freeman, Clark & Soete, 1982 Kline & Rosenberg, 1986; Martin, 2012; Mowery & Rosenberg, 1979; Perez, 2010; Rosenberg, 1994). Empirically too, the linear model has proved problematic as an explanatory tool (Kline, 1985; Mowery & Rosenberg, 1998). Whilst the recognition of change over time or in phases is identified as useful, the criticism of the linear model, as well as demand–pull perspective of innovation, is its presentation of a “single factor causality of innovation” (Walsh, 1984, p. 212). Criticism suggests that describing innovation as an exclusive action of a genius individual is problematic. Whilst the lure of the eureka myth and innovation hero remains deep and strong (Silbey, 2014, location 101), there appears to be a need to view conditions in which the individual is situated as important contributors if not determinants of innovation. There appears to be a need to look “outside” the individual in order to further our understanding of innovation. This is the focus of this research, which aims to explore the role that the dynamic environment has on the development of a particular technological innovation. A deeper critique of the innovation as heroic individual perspective will be offered in a series of points below. As much of this theory is represented as retrospective studies of successful innovators, the critique below will be also framed from the perspective of these individual cases.

2.1.1 **Individuals have a history of failure and success**

The genius model of innovation appears to break down when viewing the careers of recognised geniuses over an extended time. Often revolutionary innovators, those that are famed for their ability to think differently to the rest of culture, are, on other issues, or at other times, dramatically conservative.

Edison was an acclaimed innovator for his achievements in respect to electricity, but later in his career, with the emergence of the alternating current electricity system chiefly promoted by Westinghouse, Edison became a “staunch and then rabid defender” of the direct current system (Hughes, 1986). Rather than accepting the progressive alternating current system, Edison launched a dramatic and often deplorably graphic attack on alternating current, electrocuting animals to promote the alternating current system as dangerous and unsafe (Hughes, 1986; Millard, 1992). Edison’s commitment to direct current led to what was referred to in the press as “the battle of the systems”, and it damaged the perception of Edison as a forward-thinking radical innovator (David, 1992). By the end of the battle, and with alternating current emerging as the new dominant standard, Edison was described as “having lost touch with the rapidly changing technology” (Hughes, 1986, p. 193), changing some of the public’s view of him: “In 1879, Edison was a brave and courageous inventor; in 1889, he was a cautious and conservative defender of the status quo” (Passer, 1972, p. 72). Another example of this is Henry Ford, acclaimed innovator responsible for the Model T Ford, the mass-production method (Hounshell, 1985), and five-dollar-a-day wages (Raff, 1988). Later in life he was also known for his strong anti-Semitic views (Ribuffo, 1980) as well as heavy-handed staff abuse caused by Ford’s appointment and endorsement of Harry Bennett, who had strong Mafia connections and was only removed after Ford himself was replaced (Brinkley, 2003). Whilst Ford has proven dramatically innovative in some ways, in other ways his methods and thinking have proved dramatically wrong.

These examples show that whilst we think of great innovations as the achievements of great minds, it seems incomplete to assign their innovation achievements entirely to their own genius. Over the long course of careers of heroic innovators, often they have displayed characteristics that are anything but innovative, uncharacteristic (and refreshingly) as normal as anyone else of their time. It was a view shared by Henry Ford himself: “To teach that a comparatively few men are responsible for the greatest forward steps of mankind is the worst sort of nonsense” (cited in Hardagon, 2003, pp. 45–46). Whilst the individual remains chief actor, there is a need to look outside the individual for further refinement of our understanding of innovation.

2.1.2 **Genius ideas are not unique to recognised “geniuses”**

Furthering this perspective, often world-changing ideas are recognised by many people prior to the emergence of a single innovator. Through history, it appears that often the same or very similar ideas are recognised by multiple independent people over time (Arthur, 2009; Merton, 1973). In science fiction and in arts, history is replete with examples of individuals who have presciently identified innovative technologies long prior to the individual who became the recognised innovator. Da Vinci provided primitive drawings of airplane concepts long before the airplane developed (Fagerberg, 2004), a Tintin comic book about travelling to the moon, *Destination Moon* (Hergé & Turner, 1953), was written before NASA was founded. Describing these phenomena as “technological visions”, Basalla (1988) acknowledges that these types of successful forecasts are common, and today we are living in a world surrounded by many technologies forecast by science fiction (Basalla, 1988, pp. 75–76).

This phenomenon is not limited to science fiction. Inventors and entrepreneurs too actively have attempted to build radical innovations and failed badly, only for other entrepreneurs to pursue the same or similar ideas at a later stage and achieve radical innovation success. In 1821 for example, Charles Babbage began work on his analytical engine, which was a steam-driven mechanical calculator (Arthur, 2009). Despite the device being cited as a precedent to modern computing (Swade, 2001), Babbage was a failure in his own time. One hundred years after his death, what Babbage had envisioned and spent so much time pursuing became a relatively straightforward creation, with the later vindication of Babbage’s ideas leading Clarke to identify that his failure was “not one of imagination: it lay in being born a hundred years too soon” (Clarke, 1973, pp. 15–16).

These accounts are problematic for the linear model, as by marking ideas as the initiator of inevitable innovation, the linear model cannot address why the first person to conceive of an idea fails to achieve innovation success. In contrast, many individuals have had world-changing ideas but have not achieved innovation (Cusumano, Mylonadis & Rosenbloom, 1992; Bijker, Pinch, Hughes & Douglas 2012, p. 58). Most people, despite having the right ideas, have been lost to history. And as a consequence, it appears that some of the most recognised innovators of history directly or inadvertently copied failed ideas that preceded them (Freeman, Clark & Soete, 1982; Mowery & Rosenberg, 1979; Stigler, 1980; Tuomi, 2002, location 2380). At a fundamental level, this discussion suggests that innovation is something more than a spontaneous consequence of great individuals (Tushman & Anderson, 1986, p. 440).

2.1.3 **At certain times, ideas appear not to rely on any one particular individual**

A final reason to reconsider the role of the individual, and also to explore the concept of environment, is that often innovative, world-changing ideas are identified by many people in independent contexts at eerily similar times (Arthur, 2009). There appear certain times when the conditions of a discovery for a particular idea appears “in the air” (Godin, 2014; Taymans, 1950), and in such conditions the idea is quickly crystallised and fully expressed by many independent people. This phenomenon has been recognised and explored in a number of theories. Kuhn described this phenomenon as “simultaneous discovery” (Kuhn, 1959), and Merton similarly described it as “multiple independent discovery” (Merton, 1961, 1963). The conclusion from this is to describe new creation as not individual genius but instead as a social phenomenon, where at certain times conditions reveal a particular idea to all those within a particular context.

There are many examples of ideas that can be described as simultaneous discoveries. Calculus (created independently by Isaac Newton and Gottfried Wilhelm Leibniz (Hall 1980)) and the theory of natural selection (Charles Darwin and Alfred Russel Wallace presented jointly on the same findings in 1858 (Darwin & Wallace, 1958)) are prominent examples in scientific theory. A detailed Wikipedia entry on multiple discoveries includes a long list of many independent discoveries of the same phenomena at identical times by independent individuals, including scientific description of oxygen and helium, the telegraph, the Bessemer process, and the recognition of the stratosphere, among many others.

The recognition of simultaneous discovery again further promotes the need to view conditions external to the individual as a significant contributor to innovation. The individual, whilst certainly the catalyst and certainly the spokesperson of individual discoveries, is operating in conditions that have an influence on their achievement.

2.1.4 **Summary**

Summarising this argument, there is a recognised need to look outside the individual as the source of innovation. There are many people who throughout history have conceived of ideas for product innovation, yet most don’t achieve innovation. Whilst this points to the discriminating factor being the individual involved, in successful cases of world-famous innovators, often their thinking on other issues or at other times does not display the thinking befitting of the title of genius, suggesting there is perhaps more to innovation than personality. Whilst the individual has been a focus of our understanding and theory of innovation historically, particularly in the linear model, there is a need to look beyond a single factor to advance our understanding. Exclusively individualist perspectives of innovation, whilst certainly capturing something fundamental about individual human achievement, in other ways appear deficient to describe the phenomenon of innovation in a complete way. To advance beyond this isolated individualist perspective, this study seeks to explore the role of the dynamic external environment in the achievement of a particular technological innovation.

2.2 Innovation as systems

The innovation systems perspective has emerged as a response to the linear model and offers advance by recognising that ideas and individuals are dependent on more than just themselves to create innovation (Fagerberg, 2004; Tuomi, 2002 p. 105). The systems perspective instead recognises that any idea is embedded in a surrounding context or structure, which has the capacity influence and perhaps even determines the utility and performance of the idea.

The innovation systems perspective addresses the deficiencies of the heroic individual perspective by acknowledging that any individualist perspective viewing any single factor (be it individuals or infrastructure or anything else) as the sole determinant of innovation is problematic (Rosenberg, 1995). The innovation systems concept describes innovation as “both an individual and a collective act” (Hekkert, Suurs, Negro, Kehlmann & Smits, 2007, p. 415) where the individual remains recognised as a prime actor but is operating in a complex mix of technological, social, economic, and political enablers and constraints (Bertalanffy, 1968 location 327; Fagerberg, 2002; Hekkert & Negro, 2009; Landau & Rosenberg, 1986; Suurs & Hekkert, 2009). This system in which the individual is embedded has the capacity to both enable and cajole ideas, bringing some outcomes forward and restraining the potential of others.

The importance of systems is reflected in a great deal of analysis of technological innovation (Lundvall, 2007; Nelson & Nelson, 2002; Nelson & Rosenberg, 1993). Freeman and Soete (1997, location 6725), for example, provide a summary of the successful industrialisation of the British economy, acknowledging it to be best understood as a result of a complex system: “Historians (von Tunzelmann, 1993; Mathias, 1969) are generally agreed that no single factor can explain this British success. Rather it can be attributed to a unique combination of interacting social, economic and technical changes within the national economic space”. Extending this example of Freeman and Soete (1997, location 6725), in contrast to the linear model, it suggests that if Watt, the famed genius who created the steam engine, lived and worked in Outback Australia instead of being embedded in the British economy, he may not have conceived of the steam engine, despite having the same neurological capacity for ideas.

Innovation systems theory has become a significant component of the innovation literature (Carlsson, Jacobsson, Holmen & Rickne, 2002; Chaminade & Edquist, 2006; Fagerberg & Srholec, 2008) and a popular innovation policy tool (Balzat & Hanusch, 2004; Hekkert et al., 2007). As Hekkert et al. (2007, p. 414) identify, “Both science and policy community recognize ever increasingly that technological change and its resulting innovations are best understood as the outcome of innovation systems”. Because of its suggestion that the innovation capacity of an idea lies outside of the idea itself, much of the focus of theory addresses similar concepts to this research focus: What conditions influence and perhaps lead to innovation? In comparative studies, how do systems differ and how does this manifest in different performance outcomes? These questions are certainly relevant to the research questions of this study.

2.2.1 What is a system?

There are three important concepts that help identify systems: Components, boundaries, and purpose (Bertalanffy, 1968). The first is the identification that a system is made up of a network of interactive components – also called elements (e.g., Musiolik & Markard, 2011), subsystems (e.g., Schnabl, 1995), or nodes (e.g., Cooke, Roper & Wylie, 2003). These components do things. Using the example of the human body as a system, the components are the organs (heart, lungs, etc.), each of which exhibits some specific characteristic that contributes performance to a larger system. For the larger system to work effectively, the components need not only to perform their role effectively but must also be balanced against other components; the lungs need the heart which needs the lungs, and so forth (Ackoff, 1994). The second concept is boundary. Systems are not universal – they have a boundary. A boundary is like a skin: It creates an inside and outside. The boundary makes the distinction to the wider environment in which the system is placed (Ackoff, 1994; Carlsson et al., 2002; Carlsson & Stankiewicz, 1991). The third important concept of systems is purpose. A purpose defines the difference between a network and a system. The components must be working together to achieve a purpose or exhibit a performance that is different or greater than any individual component (see also 'wholism' of Kuhn, 1962). The purpose of a system is not teleologically predetermined but rather may emerge from the presence and characteristics of the connected components.

2.2.2 Different types of innovation systems

Innovation systems are a particular application of the more general systems concept (Freeman, 1995; Lundvall, Joseph, Chaminade & Vang, 2011; Nelson, Mowery & Fagerberg 2005), attempting to specifically describe systems that influence and lead to the outcome of innovation (Chaminade and Edquist, 2006). As a result of theoretical and empirical research, four specific innovation system types have emerged (Carlsson et al., 2002, p. 234): National innovation systems (Freeman, 1995; Lundvall & Bengt-Ake, 1992; Nelson, 1993), regional innovation systems (Cooke, Gomez Uranga & Etxebarria, 1997; Saxenian, 1996), sectoral innovation systems (Breschi & Malerba, 1997; Malerba, 2002), and technological innovation systems (Bergek et al., 2008; Carlsson & Stankiewicz, 1991; Hekkert et al., 2007). These can be viewed as a series of levels, moving from the macro (national innovation system) to the meso (regional and sectoral level systems) to the micro level (technological innovation system). With recognition that these different systems do different things (Edquist, 2006; Carlsson et al., 2002, p. 233), each level offers a different conceptual lens through which to view phenomena, with each having a particular focus and explanatory capacity.

This research is concerned exclusively with the individual technological level. This study is specifically investigating the environmental and timing conditions for a particular technology and, as such, the micro level of the technological innovation system theory is relevant. The other levels – national, regional and sectoral – are not relevant to the research question. As such, national, regional, and sectoral innovation systems will no longer be discussed, and the following section will now exclusively investigate the technological innovation system level.

2.3 Technological innovation systems

The definition of a technological innovation system shares a similarity with other system definitions and should be seen simply as a specific application of the innovation system concept to the level of individual technology. Defining technological innovation systems, Carlsson and Stankiewicz (1991, p. 94) identify that the level offers insight into technological social, economic and political factors involved in the generation, diffusion and utilisation of a technology (Carlsson & Stankiewicz, 1991, p. 94).

2.3.1 **Recent developments in technological innovation system theory**

As a result of its individual technological focus, unique theoretical concepts to this level have emerged. Specifically, in recent years there have been some significant developments in Technological Innovation System (TIS) theory with the creation of the TIS functions model (Bergek, 2002; Edquist, 2006). The TIS functions model is an advance on the TIS concept and attempts to describe the activities that occur within any TIS that impact its innovation performance, which is contrasted to previous systems research which stopped with the identification and analysis of system structure (Bergek, 2002; Hekkert et al., 2007; Bergek et al., 2008). Bergek, Carlsson, Lindmark, and Rickne (2005) note that for a technology to achieve innovation, the seven functions of the TIS model need to be served. If a particular function is not served or is inadequate in its performance, this can constrain the innovation performance of the TIS as a whole (Bergek, Jacobsson & Sandén, 2008; Negro, Hekkert & Smits, 2007; Suurs, 2009, p. 65).

Originally nine functions were presented (Bergek, 2002), which have now been parsed (Bergek et al., 2008; Hekkert et al., 2007), resulting in a model that includes seven functions. These seven functions are summarised from Bergek et al. (2008) and the related Hekkert et al. (2007) in the following table:

Table 2.1. Technological Innovation Systems Functions model

Function name	Description	Examples of Indicators/Data types (Bergek, Hekkert & Jacobsson 2008, p. 16-17)
1. Knowledge Development and diffusion	The state of tacit and codified knowledge specific to the TIS, including different types such as technical, design, distribution and others.	R&D Projects, Patents, Bibliometrics, Investments in R&D, Learning curves, Number of workshops and conferences, Size and intensity of learning networks.
2. Influence on the direction of search	Search processes that happen within the TIS. Clarity and consensus of expectations about the direction of the TIS.	Factor/product prices, regulatory pressures, government/industry targets regarding the use of a specific technology, estimates of future growth potentials, articulation of interest by leading customers.
3. Entrepreneurial experimentation	Amount of TIS specific entrepreneurial activity.	Number of new entrants, number of diversification activities of incumbent actors, number of experiments with the new technology, degree of variety in experiments (e.g. number of different applications).
4. Market formation	TIS specific consumer market.	Number size and type of markets formed, timing of market formation, drivers of market formation (e.g. support schemes).
5. Legitimation	Strength of relationships and alignment with key institutions in comparison to competing technologies.	Volume of capital and venture capital, volume and quality of human resources (educational data) volume and quality of complementary assets
6. Resource mobilisation	Capacity of the TIS to marshal relevant human, financial and physical resources.	Attitudes towards the technology among different stakeholders, rise of growth of interest groups, extent of lobbying activities, political debate in parliament and media.
7. Development of positive externalities	Momentum of the TIS as a whole, as well as the development of support industries such as press and complimentary products.	Strength of political power of TIS actors, activities aiming at uncertainty resolution, existence/development of clear division of labour, specialised intermediaries and/or a pooled labour market information and knowledge focus.

The function model has been recognised as an important theoretical development in the innovation systems literature (Edquist, 2005; Markard, Raven & Truffer, 2012, p. 959) and has proved a popular empirical tool (Bergek, 2012; Flangan, Uyarra, & Laranja, 2011) used to investigate individual technologies from a range of industries (Fogelberg & Sanden, 2008; Foxon, Hammond & Pearson, 2010; Gebreeyesus & Sonobe, 2012; Negro et al., 2007; van Alphen, Noothout, Hekkert, & Turkenburg, 2010; Suurs & Hekkert, 2009; Suurs, Hekkert, Kieboom, & Smits, 2010). Bergek (2012) identified 60 functions of specific research papers, with seven of these being conceptual (primarily Bergek et al., 2008; Hekkert et al., 2007), and 53 being empirical.

2.3.2 **Technological innovation system dynamics**

Along with the empirical work exploring the functional characteristics of individual technological innovation systems, there is also acknowledgement within the TIS literature of the importance of systems dynamics. A TIS is acknowledged not to be static but instead dynamically changing over time, which impacts its characteristics and innovation performance. This was identified in the TIS literature from some of the earliest research (Carlsson & Stankiewicz, 1991; Johnson, 2001). Whilst it hasn't been a major focus in the empirical work, more recently there has been a renewed call for the importance of understanding system dynamics (Bergek, Hekkert, & Jacobsson, 2008; Hekkert et al., 2007; Suurs & Hekkert, 2009). Hekkert et al. (2007), for example, suggest that understanding dynamics is a critical task that must be addressed in the TIS functions literature: "In order to understand technological change, one needs insight in innovation system dynamics. New laws, entry of new actors, and other events change the character of an innovation system over time" (Hekkert et al., 2007, p. 417). More recently, Suurs and Hekkert (2009, p. 1006) further this, by offering TIS functional analysis which attempts to understand "the logic of a sequence of events", focusing centrally on dynamics.

Systems dynamics are recognised in a specific way in TIS theory. Drawing from the lifecycle model literature (Klepper, 1996; Williamson, 1973), two identified system phases are presented that represent dynamics (Bergek, 2002). Adolescent systems are described as being in a "formation phase" (Bergek et al., 2008; Hellsmark, 2010) characterised by "uncertainty in terms of technologies, markets and regulations; by institutional change, small niche markets; entry of many firms; and the formation of 'political networks' or advocacy coalitions" (Bergek et al., 2005, p. 16-17), and those systems closer to maturity are described as being in a "growth phase" (Jacobsson & Bergek, 2004; Bergek & Jacobsson, 2003, p. 7), where the "focus shifts to system expansion and large-scale technology diffusion through the formation of bridging markets and subsequently mass markets; hence the need for 'resource mobilization' increases by orders of magnitude" (Bergek et al., 2008, p. 420). By identifying what phase the system is in, it allows for analysts to make appropriate recommendations about how to improve performance (Hellsmark, 2010; Suurs, Hekkert, Kieboom & Smits, 2010). To make the distinction between the two phases, Bergek et al. (2008) stress that the formative phase "is not characterised by a rapid growth rate of diffusion or rapid growth in economic activities. On the contrary, the volume of activities is small and many experiments take place – the TIS is in a process of formation" (Bergek et al., 2008, p. 416).

The recognition of system dynamics, and the recognition of two different system phases, offers the most relevant tool so far for this research. Having the capacity to differentiate a system in a formative phase, compared to a growth phase, offers the capacity to potentially describe why innovation only emerges briefly, rather than being possible at all times. However, with more specific analysis, the identification of only two system phases appears limited. With only two different system states there appears only limited capacity to describe the cause of change. Related to this, there are some fundamental limitations of how the TIS functions model addresses dynamics and boundaries that have seen it receive recent critique (Markard & Truffer, 2008).

2.3.3 **Critique of technological innovation systems function model**

Despite the recognition of the need to acknowledge dynamics with the TIS literature, currently the model doesn't have a particularly strong capacity to do so. Recognising only two different system phases is thought inadequate as currently the model does not describe what leads to system formation or what initiates transition between phases (Markard & Truffer, 2008). Whilst the TIS literature promotes the importance of dynamics (Bergek, Tell, Berggren & Watson, 2008; Hekkert & Suurs 2009; Suurs, 2009), the toolkit the model offers to investigate and describe dynamics is limited. Bergek et al. (2008) identify that the phase concept, and dynamics more generally, is an area of the model which is underdeveloped and which needs further theoretical advance: "We acknowledge that more research is needed to establish the nature of the different phases" (Bergek et al., 2008, p. 420). Whilst it is described in the literature that the need for a better expression of dynamics is on the agenda for future research, it is suggested that there are two more fundamental reasons why this aspect of the model has remained underdeveloped and perhaps can never be resolved: Quasi-static methodologies and internal orientation problems arising from system boundaries.

2.3.4 **Quasi-static methodologies**

Despite the recognition of the importance of dynamics (Hekkert et al., 2007), in the TIS literature there is limited application of methodologies to capture dynamics, and it is acknowledged that the main empirical methodologies employed within TIS functions literature to describe dynamics are quasi-static (Hekkert et al., 2007; Suurs, 2009). This methodology describes dynamics through variance – comparing two cross-sectional snapshots of the system at two points in time (Hekkert et al., 2007; Langley, 2007). This methodology suggests the presence of change – how a system is different at different points in time without a more detailed perspective on what caused the change.

The application of cross-sectional methods to describe system dynamics was recognised to be problematic from some of the earliest stages of the TIS functions literature. Carlsson et al. (2002, p. 234) identified that, “In a system with built-in feedback mechanisms, the configuration of components, attributes, and relationships is constantly changing. Thus, a snapshot of the system at a particular point in time may differ substantially from another snapshot of the same system at a different time” (Carlsson et al., 2002, p. 234). The problems with cross-sectional system research – and by contrast the need instead for longitudinal understanding – also reflects a similar early methodological directive of Schumpeter (1942) for system researchers:

> Since we are dealing with a process whose every element takes considerable time in revealing its true features and ultimate effects, there is no point in appraising the performance of that process ex visu of a given point of time; we must judge its performance over time, as it unfolds through decades or centuries. A system- any system, economic or other- that at every given point of time fully utilises its possibilities to the best advantage may yet in the long run be inferior to a system that does so at no given point of time, because the latter’s failure to do so may be a condition for the level or speed of long-run performance. (Schumpeter, 1942, location 1837)

This issue may be addressed in future research. Hekkert et al. (2007) and Suurs (2009) have strongly promoted the need to further investigate TIS dynamics and suggest longitudinal process methodologies such as that of Van de Ven et al., (1999) as a way to advance the theory (Suurs 2009). Despite this, most empirical research remains cross-sectional, and there appears to be resistance to a further advance of the model as a longitudinal process theory (Bergek 2012), leading to the TIS functions model being described as “myopic with regard to the explanation of technological transitions” (Makard & Truffer, 2008, p. 610).

2.3.5 **Internal orientation**

The second criticism of the functions model is the way in which the system concept creates a strong internal and external environment for the purposes of analysis, largely disregarding the external environment (Markard & Truffer, 2008). In much of the TIS literature, system development is described as a process driven by things inside the system, where the system operates independently of the environment, and by improving the performance of the internal components of the system, the performance of the innovation system as a whole will improve. There is, however, little guidance as to the role that things external to the system have on the systems performance, or if, how, and when things cross the boundary to move from external to internal. The TIS functions model consequently has been recognised as inwardly orientated, omitting the impact of the system's environment on the performance of the system itself (Makard & Truffer, 2008, p. 610). In response, Bergek (2012) suggests that whilst the functions model does have the capacity to include the external environment (see, for example, the application of the concept of cumulative causation (Suurs & Hekkert 2009), for the most part this has not occurred in existing TIS research.

The focus on internal attributes of the system is marked in the foundations of the model. Reviewing the definitions of the TIS functions model offered in the literature, the focus on internal components appears prominent: "Inherent in a systems view is a notion that all system components contribute to the 'goal' of the system or they would not be considered part of that system. The contribution of a component or set of components to the goal is what is here called a function" (Bergek, 2002, p. 21). Hekkert et al. (2007) too suggest: "The analysis of technological change should focus on systematically mapping the activities that take place in innovation systems resulting in technological change" (Hekkert et al., 2007, p. 415).

This internal orientation of the TIS functions model is proving problematic (Markard & Truffer, 2008), reflected in uncertainty at the empirical level. Smith et al. (2010) for example, suggest that with respect to the existing sustainable energy TIS analysis (biogas, wind farms, etc.), with no recognition of the effect of the external environment (technologies, consumer preferences to competing technologies, etc.), the TIS functions model does not provide any capacity to identify what is missing from TIS in focus to achieve innovation and where solutions to weaknesses can be found:

> It remains unclear where these absent functional capabilities come from, or how they develop… Much of that explanation rests in the broader societal contexts in which specific innovation systems operate, and which tend not to be considered. (Smith et al., 2010, p. 438)

Extending these ideas, Tigabu et al. (2015) recently investigated the evolution of renewable energy TISs in East Africa, progressing further than Smith et al. (2010) to suggest more definitively that the determinants of innovation appear to lay outside analysis provided by the TIS function model:

> Development is determined more by national and international contextual factors than by specificities related to technologies or internal dynamics. (Tigabu et al., 2015, p. 1)

The internal focus appears to be a characteristic of the TIS functions model that has significant implications for its capacity. Much like the linear model and demand–pull theories that have been rendered ineffective because they problematically isolate ideas from the wider context in which they emerge (Mowery & Rosenberg, 1979; Rosenberg, 1994), the TIS functions model in its current form appears to repeat the same problem, largely isolating the TIS from the environment in which it is embedded. Like the criticism of the linear model presented earlier in the chapter (Freeman, 1991a, 1996; Kline & Rosenberg, 1986; Martin, 2012; Mowery & Rosenberg, 1979; Perez, 2010; Rosenberg, 1994), it is suggested any particular TIS, like any particular idea or individual, is dependent on more than itself to create innovation.

2.3.6 **Problems of applying the system concept at the micro level**

In analysing the cause of the lack of recognition of the external environment, it is suggested that the largely exclusive internal focus of the TIS functions model is not an oversight of TIS researchers, but instead a more fundamental problem related to the application of the systems concept to the micro individual technological level, specifically related to the issue of boundaries (Carlsson et al., 2002). As discussed in the section above, boundaries represent a central element of the systems concept (Ackoff, 1994), requiring distinction between an internal and external environment. To define a system, a requirement is to define a boundary to that system. At macro system levels, such as the regional or national innovation system level, boundary conditions are less dynamic and more obvious. There is less dynamic transfer of components between the inner and outer environment which makes the systems in focus more stable and makes analysis easier.

The components of national level innovation systems for example (such as economy-wide R&D spending, monetary policy, or population education levels), are comparatively stable (Lundvall, Johnson, Andersen & Dalum, 2002; Malerba, 2002), as national systems have much more organic or obvious boundaries that do not quickly change- Australia's and Denmark's national innovation systems have obvious geographic limits which make boundaries to these national systems easy to define. In comparison, at the micro individual technological level, technological innovation systems are much more dynamic. A technology can change rapidly, drawing or combining with many different new capacities from the external environment at a much greater and faster frequency (Adner & Levinthal, 2002; Arthur, 2009; Basalla, 1988; Constant, 1980; Levinthal, 1998). A component that exists in the external environment may be rapidly deployed and transferred to the internal environment, making the separation between internal and external environments much more difficult and critical as a conceptual issue. Components, people, ideas that were for the longest time not evenly remotely relevant to the technological system in focus may become relevant, perhaps in dramatic fashion. The drawing in of these things previously external and irrelevant to the system may result in a fundamental change in the nature of the system, rather than being describable simply as an obvious stage of development of the previous system, and with this fundamental change, it calls into question the recognition of a system at all, if this system is entirely reconfigured and dependent upon things external to it. Discussing the impact of the external environment on aircraft technology, for example, Mowery and Rosenberg (1998) and Rosenberg (1979) identify that through its development, aircraft technology relied on new technologies developed in external industries which were not initially designed specifically for the purposes of aircraft (such as steel and petroleum). Similarly, Utterback and Suárez (1993, p. 2) contend that the external environment appears so important to the source of innovation for individual technologies that often, internal firms are at a disadvantage compared to external firms: “Innovative firms often come from outside the industry in question” (Utterback & Suárez, 1993, p. 2). This suggests that the problems of dynamism and interaction between the internal and external environment are not significant at macro system levels such as the national innovation system level or regional level; however, at the micro technological innovation system level the external environment is critical.

Drawing sharp boundaries between the external and internal environment, or largely excluding the external environment, which appears central to the systems concept as well as its application in the TIS functions model, inherently misses much of the important dynamic activity that the TIS functions concept attempts to capture. What is external to the system at any point in time, and outside the bounds of TIS functions analysis, may be what is constraining development. A particular technology may entirely rely on things external to the system in order to achieve innovation, marking the systems concept only useful after these things have emerged. By the time a clearly definable system emerges for a particular technology, and where a boundary has stabilised, the system may have reached a state of stasis, where much of the important creation work has already concluded (Gould & Eldredge, 1977).

2.3.7 **Assessment of the Technological Innovation Systems Function model**

With its almost exclusive focus on describing system dynamics as an internal process (Markard & Truffer, 2008), in its current form the TIS functions model has limited capacity to offer guidance to address the research questions. Due to sharp boundaries it draws between the internal and external environment, the model fails to capture important environmental phenomenon which impact the creation and diffusion of individual technology and has little capacity to describe how transfer between the internal and external environment occurs. Equally, despite the acknowledged significance of dynamics (Hekkert et al., 2007; Bergek et al., 2008), there is a limited range of conceptual tools to describe them, with the two phases to represent dynamics acknowledged to need further advance (Bergek et al., 2008), which is also manifest in the large amount of variance research rather than longitudinal research within the literature (Hekkert et al., 2007). For these reasons, despite the focus on viewing factors outside the individual as the source of innovation which suggested strong relevance to the research question of this study, the TIS functions model, and the TIS concept more generally, is viewed as limited and will not be utilised.

2.4 Innovation as process

So far, the literature review has presented a number of issues. First, it identified that the heroic innovator perspective is limited in isolation, and there is a need to look outside of the individual in order to more deeply describe the determinants of innovation. Pursuing this, the innovation systems theory was identified. With its focus on describing innovation as both an individual and collective act, the theory appeared useful for this research, having a similar ambition of describing the wider context of ideas. However, exploring the technological innovation systems level, it was noted that there were a number of problems in implementing this theory. Specifically, that the requirement of boundaries makes a strong distinction between the system and the environment, with the theory not adequately accounting for the environment's role in development or eventually in innovation. Along with this, the importance of dynamics, how the innovation changes over time, whilst noted as important, was not a strong theoretical or empirical focus of technological innovation systems functions literature.

Innovation process theory offers capacity to address these issues and is the focus of this research. Process theories offer capacity to explore both the dynamics of innovation and how opportunities change over time, as well as the role of the environment as an influence on innovation. This section will identify why process theory is most suitable to address the research questions as well as identify the deficiencies in current process theory with respect to environment, which this research can address.

Innovation process theory has become an important stream of the innovation literature (Garud et al., 2013). In process theories, innovation is not seen as a discreet event but, instead, as a process of development with innovation being an outcome of extended evolution of a set of variables (Basalla, 1988; Perez, 1983). In contrast to most of the technological innovation systems empirical research, as well as more generally static equilibrium-style models that discuss innovation by referencing its effect (Rosenberg, 1994), process theories represent and focus on how innovation occurs by acknowledging it as an unfolding sequence with a temporal pattern (Garud et al., 2013; Van de Ven & Poole 2005). Under conditions of uncertainty (Perez, 2010, p. 36), innovations are constructed based on complex sequences that are dynamic, path-dependent at times (Arthur, 1989), interacting at multiple levels (Geels, 2002, 2004, 2005; Rip & Kemp, 1998), historically connected (Basalla, 1988; Unruh 2000), complementary-dependent (Mowery & Rosenberg, 1998), and displaying their own maturity processes (Anderson & Tushman, 1990; Dosi, 1982; Klepper, 1997; Utterback, 1978).

There is a large amount of innovation theory that can be classified as process theory (Garud et al., 2013; Geels, Hekkert & Jacobsson, 2008, p. 526; Pavitt, 1984; Van de Ven, 1992, p. 171). These individual theories describe many different aspects of innovation as processes. These process theories have been used to describe how economies change (Kuznets, 1940; Perez, 1983; Schumpeter, 1939), the individual process of creation (Ogburn, 1955; Usher, 1954), the changing role of users in the development of innovation (Bijker, 1997; Rogers, 1995), the process of technology creation (Nelson & Winter, 1977, 1982), technological competition (Christensen, 1997; Suárez, 2004), and technological trajectories (Dosi, 1982, 1988), among others.

One branch of innovation process theory particularly relevant to this research is the innovation lifecycle literature. Rather than focus on processes influencing a technology at a particular stage, lifecycle models attempt to map the complete development process from inception of a technology to achievement of innovation (Dosi, 1982; Klepper, 1997; Nelson & Winter, 1977; Perez, 2002). These models explore the process of how successful innovative technologies emerge first as invention, proceed through development, and eventually transform into innovation (Garud et al. 2013, p. 777). Innovation lifecycle models present this in a number of phases. Summarising these phases in popular lifecycle models (Abernathy & Utterback, 1978; Anderson & Tushman, 1990; Dosi, 1982; Nelson & Winter, 1982; Ogburn, 1950; Perez, 2002, 2010; Suárez, 2004; Usher, 1954), the following appears to be the development process of a technology:

1. Gestation of prior technologies occurs in the environment.
2. At some point the technologies offer conditions that lead to invention of a new technology.
3. This new technology is initiated as adolescent in performance but spurs a large volume of new entrants sensing potential for dramatic innovation.

4. The large volume of entrants offers products as variations on the initial design. These reveal preferences and problems, and, despite momentary glimpses of success, innovation proves elusive.

5. At some point a new product will be released that becomes widely accepted by customers and becomes recognised as a dominant design and defining product of the category.

6. This results in a large “shakeout” as competitors leave the market, and there emerges an oligopoly structure where the creator of the successful design will capture the majority of value for the entire market.

These theories offer a description of these phases often with similar yet distinct terminology, presented as sequential phases. Abernathy and Utterback (1978), for example, describe a new technological innovation development in three phases: A “fluid phase”, “transition phase”, and a “specific phase”. Perez (2002, 2009) describes how technologies become embedded in the economy in a four-phase process: “Irruption”, “frenzy”, “synergy”, “maturity”. Ogburn (1950) describes innovation from the perspective of the individual as a four-phase process: Invention, accumulation, diffusion, adjustment (Ogburn, 1950, p. 393). This is similar to Usher (1954), who also offers a four-phase model: Perception of an incomplete problem, setting the stage, act of insight, critical revision and full mastery.

These lifecycle models are viewed as credible (Garud et al. 2013), with a significant amount of empirical support (Stubbart & Knight, 2006, p. 86). These models suggest a reliable and predictable path of development to a particular technology, with the implication that there will exist only a brief moment where innovation is possible, capitalised on by a single victor, to close off opportunity for all others. These theories recognise and promote the recognition of innovation as dependent on conditions at a particular time that create or are recognised by a particular or small subgroup of individuals or firms who prove successful.

Despite the empirical strength of these models, there remains opportunity for further advance, and there are some identified criticisms. First, many of them offer *representation* of process (Checkland, 1981; Checkland & Scholes, 1981), describing process by way of markers of change, rather than mechanisms. Firm entry and exit rates at certain times in development, for example, appear a strong empirical marker of the process and a focus of research (Agarwal & Gort, 1996; Horvath et al., 2001; Jovanovic & MacDonald, 1994; Klepper, 1996; Klepper & Miller, 1995; Maine, Thomas, Bliemel, Murira & Utterback, 2014). This is a useful tool, and one that offers articulation of what is otherwise a very difficult process to identify. However, there remains possibility to explore further markers, particularly of the environment, if not attempt to describe what is causing the change, rather than offer tools that allow for its recognisability.

A second criticism is one levelled at most linear innovation models (Freeman, 1991a, 1996; Kline & Rosenberg, 1986; Martin, 2012; Mowery & Rosenberg, 1979; Perez, 2010; Rosenberg, 1994) and recently at technological innovation system literature (Smith et al., 2010, p. 438; Tigabu, Berkhout, & Beukering et al., 2015, p. 1). These models have a tendency to isolate the domain from its wider environment and view progress as generated by the effort of those working on the technology, as opposed to the external context or conditions in which it is placed.

Lifecycle models do not discount the environment entirely. There is recognition of external environment at particular times in the development process in a number of these models. For many lifecycle models, the wider environment is most often the catalyst for initial conditions to spark invention (such as Usher's 1954 description of "setting of the stage"). But post this, in later phases, the role of the wider environment becomes murky as focus shifts to describe the more obvious activity that emerges within the now established domain. Whilst there is continuing strong acknowledgement of the environment by some (Dosi, 1988; Nelson & Winter, 1978), what specifically comes from the environment, and how, and when, and what effect that has on innovation is not well described.

Responding to these issues and exploring the environmental context surrounding a technology, and what influence this has on innovation, are the focus of this research. There is the possibility to explore and more clearly articulate the role of the environment throughout the innovation lifecycle phases of development. But, before exploring the role of environment more clearly, a number of key theories of innovation will be presented which describe the environment as critical to innovation, offering further justification and motive for reconciling this against lifecycle models.

2.5 The importance of environment

Environmental context appears a strong and important catalyst for both invention and innovation. In alternative theories to innovation lifecycle models, there is recognition of environmental conditions as important determinants of technological innovation. At any given time there exists a broad frontier of socioeconomic and cultural influences, consumer preferences and familiarities, and industry alignments and relationships, which all interact to present complex conditions that impact the potential to create a particular technology and the performance of that technology, as well as its likelihood of innovation.

Whilst many of these issues will be explored in the next chapter, with the presentation of the lifeworld model, to articulate the relevance of the environment the theories of combination and exaptation will be described which implicitly suggest that the contextual environment at any given time is a key determinant of what technologies are created as well as their potential for innovation.

2.5.1 **Combination**

Combination has a long history of recognition in the innovation literature as a central mechanism of new creation (Arthur, 2009; Basalla, 1988; Nelson & Winter, 1982; Ogburn, 1950; Kline & Rosenberg, 1986; Schumpeter, 1939; Tarde, 1903). Schumpeter (1939) viewed it as the central act of innovation, offering his definition of innovation as simply, “The carrying out of new combinations” (Schumpeter, 1939, location 2099). More recently, it has received renewed acknowledgement (Garud et al., 2013; Van de Ven et al., 1999, location 185) and has been described once more as central to technological evolution and innovation (Arthur, 2009, location 2453).

Whilst the focus of this study is technological innovation, more generally combination appears to be a pervasive mechanism of creation in many domains (Nelson & Winter, 1982, location 1840). These range from the “nontechnical” aspects of technology creation (such as naming of technologies – e.g., Bell Lab engineers named the “Transistor” by combining the concepts “transconductance” and “varistor” (Gertner, 2013 p. 98)) to broader domains, such as artistic endeavour, science, and biology. With respect to artist endeavour, Brookes suggests combination is key to Picasso’s legacy as an innovator: “What Picasso did, for example, was take the concept ‘Western art’ and the concept ‘African masks’ and blend [combine] them together” (Brookes, 2011). Kirby (2013) too found similar outcomes in the field of music, identifying the primary means of creation for recognised innovators such as Bob Dylan and Led Zeppelin as a recombination of specific folk and blues pre-existing standards with different lyrics and electronic amplification (but apart from this, often with very little difference to the originals). In science, Tarde identified combination as the central process of theory building. Using the example of geometry, Tarde identified: “The development of a new theorem [occurs] in the mind of a geometrician through the combination of two old theorems” (Tarde, 1903, location 1160). Even earlier, Mary Sommerville in 1834 received acclaim (and was an influence of Thomas Kuhn) after writing about “connection” (combination) as the essence of science: “The progress of modern science especially within the last five years, has been remarkable for a tendency to … unite detached branches [of science, so that today] … there exists such a bond of union, that proficiency cannot be attained in any one branch without a knowledge of others” (Sommerville cited in Kuhn, 1969, p. 324). Whilst these examples have focused on combination as a concept of human creation, combination has also been described as an important mechanism of novel creation for biological systems too. Ridley identifies that "Recombination is the essential procedure in sex, the mixing of genes from the two grandparents" (Ridley, 1994, location 638). The recognition of combination in these domains suggests, as Turner (2014, location 434) does, that combination is a central act of evolution, and our advanced capacity for it in comparison to other species is a primary reason why human creation is dramatically more pronounced compared to all other species.

With respect to technological innovation, there are many examples of technologies that have been studied and described as combinations of previous technologies. Word processors (Drucker, 1986), telegraphs (Mokyr, 1990), CAT scanning technology (Adner & Levinthal, 2002), calculators (Drucker 1986), primitive stone tools (Basalla, 1988), fiber optics (Granberg, 1988), turbine jet airplanes (Constant, 1980), and automobiles (Basalla, 1988) are just a few of many examples (Arthur, 2009; Godin, 2008; Lipsey et al., 2005; Turner, 2014) that have highlighted the concept of combination (see table 2.2 below for further elaboration of these examples). With the range of these alternative perspectives all highlighting the critical role that combination has in new creation, there appears a compelling need and capacity to acknowledge, like Schumpeter does, the role of combination as a central mechanism of creation.

Each combination can be explained as drawing on components from history. In this way, too, each new combination is generative and expands the capacity of history (Fagerberg, 2002; Nelson & Winter, 1982, location 1842; Tarde, 1903, location 1160). This dual capacity of any combination means ultimately that nothing is created in isolation and consequently reinforces the importance of history. In the view of Ogburn: "The pattern of causation is like that of a network: everything is connected" (Godin, 2010, pp. 291–292; Ogburn, 1957b, pp. 20–23). Like Usher (1954) and Darwin (1859), Dennett (1995) identifies that this interconnection also suggests that "accumulation" is a pragmatic strategy of evolutionary efficiency. Rather than constantly redesigning the entire world once more, instead evolution draws as much as possible from what has already occurred (Dennett, 1996, location 1409). Both of these points identify the consistency of viewing the relationship between history and combination as central to creation.

Table 2.2 Technologies described as combinations of preceding components

Jet Engine	Both Constant and Arthur explore the jet engine: Constant: "The turbojet is heir to two centuries of turbine development, including water turbines, turbine water pumps, steam turbines, internal combustion gas turbines, and piston engine superchargers and turbosuperchargers" (Constant, 1980, p.3). Arthur too: "If you open p a jet engine (or aircraft gas turbine powerplant, to give it its professional name), you find components inside- compressors, turbines, combustion systems. If you open up other technologies that existed before it, you find some of the same components. Inside electrical power generating systems of the early twentieth century were turbines and combustion systems; inside industrial blower units of the same period were compressors (Arthur, 2009, location 279).
Motor-truck	"For example, the internal combustion engine branch was joned with that of the bicycle and horse-drawn carriage to create the automobile branch, which in turn merged with the dray wagon to produce the motor truck" (Basalla, 1988, pp. 138–139).
Word Processor	"The word processor is not so much a "scientific" invention. It hooks up three existing instruments: a typewriter, a display screen, and a fairly elementary computer. But this combination of elements has resulted in a genuine innovation that is radically changing office work" (Drucker, 1986, p. 211).
Telegraph	"The telegraph, like the railroads, was a typical nineteenth-century invention in that it was a combination of separate technological inventions that had to be moulded together. Just as the strength of a chain can never be greater than that of its weakest link, the efficiency and reliability of a system can never be greater than that of its weakest component. Long-distance telegraph required many subsequent inventions and improvements, which took decades to complete" (Mokyr 1990, location 1927).
CAT Scanning	"CAT scanning (Trajtenberg 1990) drew upon X-ray technology, which was already applied in the medical imaging domain, and computer technology, which had been applied to data processing" (Adner & Levinthal, 2002, pp. 11–12).
Calculator	"The internal processing elements of the original calculator were manufactured as discrete components that were electrically interconnected in the final design" (Merges & Nelson, 1990, p. 859)

Fibre Optics	"Technical change often involves the combination of many knowledge fields and complementary products/services. For instance, the use of fiber optics in telecommunication required the development of laser technology (Granberg, 1988).

2.5.2 **What is combination**

Combination is the action of combining existing and known elements, be they material and/or nonmaterial, to form something new (Ogburn, 1950, p. 378). Combinations can be of physical components as well as concepts (Turner, 2014, location 255). Schumpeter reflected on this too, suggesting that apart from physical products, combinations can be the combination of existing products with new production methods, new markets, new supply sources, or new organisation structures (Schumpeter, 1934, location 2099). These examples are not exhaustive. Instead more general descriptions suggest that combination can be any form of existing knowledge (Nelson & Winter, 1982; Ogburn, 1950; Usher, 1954). There are no inherent constraints (apart from physical) that limit what existing things can be combined. To use an example of Arthur (2009), it is possible to combine “jet engines with hen houses” (Arthur, 2009, location 2469), despite there not being any obvious value in doing so.

Importantly for our understanding of innovation, combinations are viewed as an act of creation. With respect to the technological combination, the identification and alignment of components requires active design work by entrepreneurs (Adner & Levinthal, 2002, p. 12; Clark, 1985), marking the concept as important to innovation. The combination must draw from the environment to identify components which must be harnessed to work effectively together and be matched against a particular purpose (Arthur, 2009). It requires both “discovery” and “creation”, as the components that need active shaping and the alignment does not occur automatically (Dosi & Egidi, 1991). Dennett (1996, location 1329), using the example of a watch, acknowledges that this process of configuration of components represents “work done”. The intricate parts of a watch, as well as their relationship to each other, do not create and organise themselves but are an act of purposive creation (see also Nelson & Winter, 1977, p. 49).

The importance of this is that whilst combination suggests that drawing things from the environment is significant, new creation and innovation can still be viewed as an act of creation. In this way, the types of combination possible at different times, and when these potential combinations are recognised, can be explored as an act of creation and subsequent innovation by the individuals involved.

2.5.3 **Exaptation as a tool of combination**

Offering an advance on the discussion of combination, and further suggesting the need to articulate how the dynamic environment has an impact on innovation, is the concept of exaptation (Gould & Vrba, 1982). Exaptation is a theory put forward by Gould and Vrba (1982) which identifies that using existing things for purposes they were not previously intended is an important mechanism of evolution. Giving a detailed example from biology, Gould and Vrba retrace how birds gained capacity and design for flight. Initially bird feathers were a tool of thermoregulation. As adaptive fitness increased feather density, some species, such as the black heron bird of Africa, utilised their dense feathers for new mantling wing techniques which gave an advantage in catching fish. This new use of feathers for an action for which they were not previously designed is recognised as an exaptation event. As the adaptive fitness of this mantling action became more pronounced in these birds, over time it created primitive wing structures. This led to a second exaptation event when these wing structures, which were originally giving advantage for catching prey, were utilised for the different and not originally intended activity of flight. Gould and Vrba's theory of exaptation suggests in this example and many others that existing species evolve through a series of adaptations which improves fitness (marked as times of stasis (Eldredge & Gould, 1972; Gould & Eldredge, 1977)), but the act of establishing a new species is initiated through an exaptation event which utilises existing characteristics for purposes they were previously not intended.

The theory of exaptation has been applied to technological evolution too, and it appears to describe an important mechanism of radical innovation formation (Adner & Levinthal, 2002; Cattani, 2006; Levinthal, 1998). It suggests that rather than new technologies being created by purposeful R&D, utilising existing technologies for new uses can unlock dramatic innovation without long articulated development processes. In a detailed study of the history of the radio, Adner and Levinthal (2002) find similar conclusions to Gould and Vrba (1982) that new radical innovations are formed by applying existing technologies to new uses that they were not originally intended.

Using the example of radio wave technology, Adner and Levinthal (2002, p. 51) identify exaptation events that achieve a number of dramatic innovations simply by changing the use of existing technologies. Describing the sequence, Adner and Levinthal (2002) recount that wireless radio began as a technology that was used only as a laboratory device by Hertz, who found it an effective tool to test Maxwell's theories of electromagnetic waves. Later, learning of Hertz's discoveries, another individual, Marconi, saw this radio laboratory device and, changing the technology only slightly, utilised it as a ship-to-ship communication tool, utilising Morse code to send messages overseas. This became a dramatic radical innovation for communication, with Marconi achieving this despite little direct investment in developing the technology. In contrast to Marconi, Maxwell did not perceive the radio laboratory device to be of any use in ship-to-ship communication. Later, with the technology now well established as a communication tool between ships and on land, another exaptation event occurred, this time led by others (including both professionals as well as amateur ham radio enthusiasts), who used it to broadcast voice and music recordings, leading to the development of a major industry in broadcast radio. This new use (exaptation) was missed by Marconi, who by that stage had built a lucrative communication empire but “completely failed to envisage” the value of his technology for the new purpose of broadcast radio (Landau & Rosenberg, 1986, p. 25). At each exaptation event, the new development of a radical innovation was achieved easily by slightly adjusting existing technologies and changing their application, rather than undertaking long arduous and unique processes of research and development. Adner and Levinthal summarise this process as it occurred in radio and suggest that it is relevant to how all radical technologies are formed:

> A technology undergoes a process of evolutionary development within a given domain of application. At some juncture, that technology, or possibly set of technologies, may be applied to a new domain of application. The technological shift necessitated by this event is modest. … The revolution is in the shift of application domain. (Adner & Levinthal, 2002, p. 52)

Exaptation appears significant to technological creation, and there are many authors who have noted it to describe something pervasive to new radical technological creation (Arthur, 2009, location 848; Dew et al., 2004, p. 70; Mokyr, 2002). The term “exaptation” provides the most decisive nomenclature for this concept, but the concept of exaptation, of utilising existing technologies for new uses they were not originally intended, has been recognised many times within the innovation and technology literature (e.g., Constant, 1980, p. 2; Rosenberg, 1983, p. 75; Usher, 1954, p. 50). There is identification of many practical examples in the history of technology (see Arthur, 2009; Mowery & Rosenberg, 1998, p. 67). Basalla provides a summary of some of these examples: “The earliest steam engines pumped water from mines, the first commercial use of radio was for the sending of coded wireless messages between ships at sea and from ships to shore, and the first electronic digital computer was designed to calculate firing tables for the guns for the United States Army” Basalla (1988, p. 141). Medical devices too appeared to be created in a similar way, with Comroe (1977) highlighting that of the top technologies to treat cardiopulmonary disease, 41% of these technologies were being used for diseases that were different to what the technology was originally created for.

Exaptation and combination describe that what is available in the environment at any given time represents a strong determinant of the capacity to create technologies as well as achieve innovation. These theories suggest a need to explore the environment further.

2.6 Research questions and summary

Innovation lifecycle theories suggest that technological innovations have strong development processes, moving through a series of phases covering the invention of the initial technology, development, and ultimate innovation. Combination and exaptation in contrast suggest that the achievement of innovation is possible without any clear or obvious development process. This is a conflict, and one that can potentially be resolved by more explicitly exploring how the environment changes over the lifecycle of a technology.

By utilising key concepts in innovation theory, a new technological lifeworlds model will be presented next. This model presents lifeworlds instead of phases, which represent and attempt to articulate the environment in which a technology is conceived and developed, and becomes an innovation.

2.6.1 **Research questions**

There is opportunity and need to reconcile external and internal theories, and to better articulate the role of external development throughout the development process of a technological innovation. This research does this with the presentation (in chapter 3) of a lifeworld model. It is also anticipated that the lifeworld model can offer a new range of new markers for the innovation process. Reflecting this, the research questions are:

1. How significant is the lifeworld to events and innovation in the case study?
2. How are combination and exaptation relevant in the development of innovation?
3. What is the relationship between the internal domain and the external lifeworld?
4. How do the dynamics of the lifeworld impact innovation?

2.7 Chapter Summary

This chapter has provided the theoretical context for this study. It provided an overview of innovation theory, identifying that the historic perspective of innovation as ideas is problematic (Tuomi, 2002). In response, the recognition of innovation as an outcome of a system is deemed more effective. Extending these ideas, whilst the identification of the system is important, investigating system dynamics appears problematic at the level of individual technology, manifest with the problems of dynamics and boundaries within the technological innovation system functions model (Bergek, 2012; Bergek et al., 2008; Hekkert et al., 2007; Markard & Truffer, 2008; Suurs & Hekkert, 2009). The innovation process literature provides a way forward. Reviewing a large amount of innovation process theory, there appears theoretical usefulness in exploring and more clearly articulating the role of the external environment throughout the technology lifecycle. This is the ambition of this research and from which the research questions were described. A summary table of the argument of this literature review is provided below.

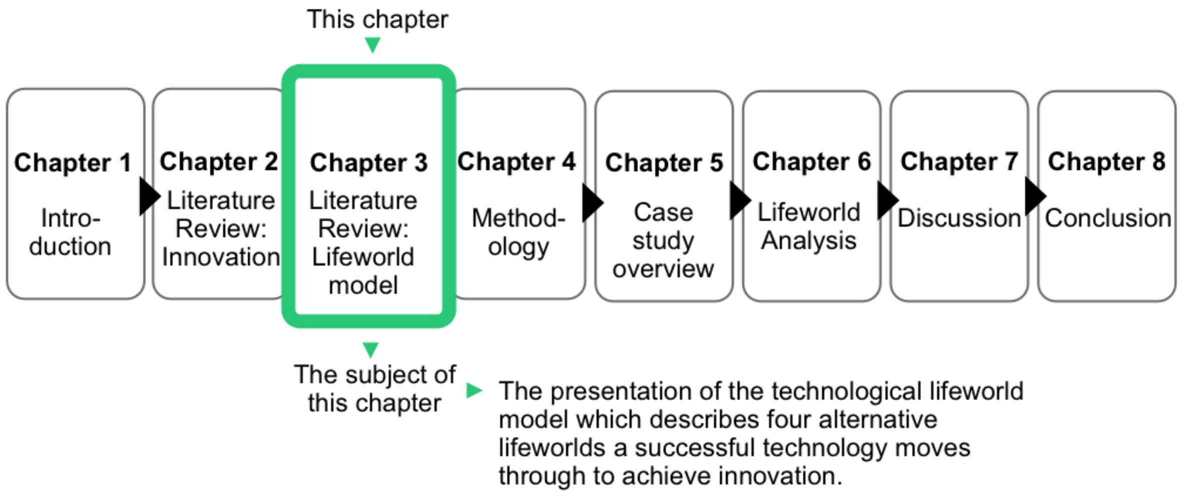
Perspective	Existing argument	Criticism
Innovation as genius	Innovation has long been described as a consequence of great individuals with great ideas, who bring forward their ideas to the world to create world changing innovation.	Criticism of this perspective suggests innovation is more than manifest individual genius, particularly when considering- the previous failures of recognised genius, that innovation ideas are not unique to those that are successful, and often more than one person can create the same idea at the same time, suggesting there are particular conditions that bring forward some ideas at certain times.
Innovation as system	Looking outside of the individual, there is recognition of innovation as both an individual and collective act, and the innovation systems concept is an expression of this. Innovation systems suggest it is a set of conditions/actors that impact innovation performance.	Whilst the system concept is useful, it is problematic at the level of individual technology, largely due to the strong boundary condition requirements to identify a system, where focus becomes describing the internal system and disregarding wider conditions.
The role of environment with reference to combination and Exaptation	There is need to explore the wider environment outside the system, with this environment referred to as 'lifeworld'. Theories of combination and exaptation suggest it is specifically the conditions in this environment outside of a system, drawing new technologies in and combining them in new ways which is critical to innovation.	Whilst the role of the environment is significant, this too doesn't describe how the environment changes, and how this can lead to new innovation at different times.

Innovation as process	How conditions change over time is important to innovation. There is a large focus in the innovation literature on process research, which expressly focusses on methodologies to explore change over time.	These process perspectives don't explo the role of the environment (lifeword) w a specific focus on the role of combinati and exaptation.

This provides the context for the study, and particularly leads to the next chapter, which is to present a deeper description of what is meant both by the concept of lifeworld, and specifically utilising existing theory to explore it as a process. This is described as the 'technological lifeworld model' and its focus is to explore how the external environment changes over time, and how this impacts the likelihood and characteristics of innovation for a particular technology. This model will then be tested empirically via a case study.

Chapter 3

Technological lifeworld model



3.0 Introduction

This chapter argues that successful innovations can be seen to pass through four particular external environments, or lifeworlds, before being a commercial success – before the time and place will be right. These are as follows: (1) Prehistory where the lifeworld makes the technology not yet possible, (2) establishment, where the lifeworld offers enabling conditions for the creation of the technology, (3) development, where trial and error advances the technology, and (4) innovation, where the lifeworld makes the technology an innovation with strong socioeconomic alignment.

The term "lifeworld" (Husserl, 1970; Ihde, 1990; Schutz & Luckmann, 1973) is used in this study to represent the collective experience and conditions, and the material characteristics and knowledge that enable and constrain the technology in focus. Similar terms used in the literature are environment, milieu, ecosystem, progress, and culture. The term "lifeworld" is used largely because it more broadly represents all conditions, even those not clearly or obviously linked to the technology in focus, which at later times may prove critical to creation. A summary of the four-lifeworld model is offered in Table 3.1.

Table 3.1 Summary of the four-lifeworld model

Prehistory lifeworld	The lifeworld is characterised by inadequate technology. The required component technology does not exist, making creation impossible. Despite this, imaginative description may be found.
Establishment lifeworld	The lifeworld offers enabling conditions for new creation. There is sufficient component technology available, and via exaptation and combination a new technology is established. The new technology itself will be limited in performance but demonstrate working capacity.
Development lifeworld	A large volume of trial and error emerges, with a dramatic number of entrants. These resulting products reveal problems with technology and expose various socioeconomic design criteria, from inputs such as consumers, regulations, suppliers, etc.
Innovation lifeworld	A successful design emerges to address the problems of preceding designs and finds alignment across social, political, and economic conditions. The technology proves difficult to dislodge and there are a large number of exits from competitors.

Each of these will now be discussed in detail.

3.1 Prehistory lifeworld

The first lifeworld is described as the "prehistory lifeworld". In this lifeworld, the technology is not possible yet, due to the lack of capacity of the lifeworld. Despite this, there may be imaginative descriptions of the technology. Overlaid in this same lifeworld there is expected to be a pre-existing parallel technology that is in a mature state with strong socioeconomic alignment.

3.1.1 **Capacity of the lifeworld**

As new technology is recognised as a combination of existing technologies (see literature review), at any given time, the availability and performance of existing technologies is a constraint to what new technologies can be created. The conditions to create a particular technology are not universal through time, but instead only become possible at certain times, dependent upon the accumulated state of available technology.

In the innovation technology literature there have been many attempts to describe how the capacity of available technologies is a determinant of new creation. In the technological literature, the role of history is a focus. Nelson and Winter (1982) for example, refer to the "vast storehouse of history" that provides tools for new creation, Heidegger (1977) refers to the "standing reserve" of all known knowledge, Ogburn (1950) refers to "material culture" from which all things draw, Usher (1954) refers to "setting of the stage", which recognises that history provides accumulating capacity, Rosenberg (1994) refers to a "frontier" from which new developments emerge, Hughes (1987) refers to history as the "seamless web" that encompasses all things, Arthur (2009) refers to the "collective of technology", and Kuhn (1962) and Perez (1983, 2004, 2009) in a similar way refer to a "constellation" of all knowledge. All of these descriptions are similar, reflecting wider recognition of accumulation in the biological evolution literature (Darwin, 1859; Dennett, 1996; Gould & Eldredge, 1977; Ridley, 1994, location 266), and all represent each author independently attempting to articulate accumulation or the role of history as an active constraint to what new technology can be created.

The Table 3.2 summarises the language used in the literature around pre-existing technologies:

Table 3.2 Summary of language around prehistory of technology

Author	Concept of history and accumulation
Arthur (2009)	"Imagine the entire collection of all technologies that have ever existed, past and present. Imagine, that is, all the processes, devices, components, modules, organizational forms, methods, and algorithms in use and ever used. If we were to list these in a catalog their numbers would be vast. This is the collective of technology" (Arthur, 2009, location 2379).
Heidegger (1977)	In a detailed, if not complicated theory of technology, Heidegger referred to the existing state of knowledge as the "standing-reserve". He suggests that we draw out new technologies and reveal new truths about the world from this existing state of knowledge through the process of what he referred to as "enframing" (Heidegger, 1977, pp. 23-24)
Ogburn (1950)	Ogburn (1950) often referred to this premise as "culture". Sometimes he referred to culture generally, but more often it was the term "cultural base" which he described as "where all new combinations comes from" (Ogburn 1950, 382, cited also in Godin, 2010, p. 295).

Author	Concept of history and accumulation
Usher (1954)	Usher acknowledged that the state of knowledge at any point in time provides the technologies that can then be applied to new problems. Usher referred to this as the "Setting of the stage" on which creation takes place, and recognised the creation of new technologies as a process of cumulative synthesis. Discussing the loom, Usher says, "The history of this development has long been obscured by writers who were unwilling to recognised the essentially cumulative character of mechanical achievements" (Usher, 1954, location 5188).
Schumpeter (1934)	Schumpeter had a strong perspective on this without singling it out as a concept itself, rather acknowledging it as part of his other theories. But as Mokyr identifies, "the bulk of Schumpeterian economic growth comes from the application of old knowledge" (Mokyr, 1990, location 242). Some examples include where he has specifically made reference to the past. For example, "The fundamental notion that the essence of economic development consists in a *different* employment of *existing* services of labor and land leads us to the statement that the carrying out of new combinations takes place throughout the withdrawal of services of labor and land from their previous employments" (Schumpeter, 1934, location 2673). Also, making mention of things within our reach: "Technologically as well as economically considered, to produce means to combine the things and forces within our reach" (Schumpeter, 1934, location 1202).
Rosenberg (1994)	"The body of presently available scientific knowledge imposes certain *constraints* on what is technologically possible and also, by the same token, permits a range of technological alternatives to be taken up within the frontiers imposed by that knowledge" (Rosenberg, 1994, pg. 12).
Hayek (1960)	"While the growth of our knowledge of nature constantly discloses new realms of ignorance, the increasing complexity of the civilisation which this knowledge enables us to build presents new obstacles to the intellectual comprehension of the world around us… The transmission in time of our accumulated stock of knowledge and the communication among contemporaries of information on which they base their action. They cannot be sharply separated because the tools of communication between contemporaries are part of the cultural heritage which man constantly uses in the pursuit of his ends" (Hayek, 1960, location 1937).
Hughes (1987)	Hughes (1987) provided the metaphor of a "seamless web" of physical artefacts, organisations, scientific understanding, and legal precedent which enable and constrain new creation.

Author	Concept of history and accumulation
Nelson and Winter (1982)	Nelson and Winter (1982, location 1840) referred to the "vast storehouse" of components from which new novel combinations are created.
Kuhn (1962)	Kuhn in his theory of scientific revolutions, refers to the constellation of facts: "If science is the constellation of facts, theories, and methods collected in current texts, then scientists are the men who, successfully or not, have striven to contribute one or another element to that particular constellation. Scientific development becomes the piecemeal process by which these items have been added, singularly and in combination, to the ever growing stockpile that constitutes scientific technique and knowledge. And history of science becomes the discipline that chronicles both these successive increments and the obstacles that have inhibited their accumulation" (Kuhn, 1962, location 169). Perez (2002) and Dosi (1982, 1988) also deserve their own recognition here, but will be included with Kuhn as both offered similar terminology for discussing Kuhn's concept of a "constellation" but applied it to technology.

3.1.2 **Components**

The importance of history is also found within any technology. Any technology can be described as a combination of component technologies, which themselves are often common technologies (Arthur, 2009; Freeman & Soete,1997; Hughes, 1983; Mowery & Rosenberg,1998; Perez, 2002).

This perspective should be contrasted to the heroic innovator perspective. In the past, technologies were studied and described as complete creations, where the person responsible would deliver a unique technology independent from all others (Godin, 2008). From this perspective, the act of invention brought the technologies to life, and the person who created it also conceived of all requisite internal components required by the invention (Tuomi, 2002, location 190). In 1842, for example, a commentator on British industry described the steam-engine as an artefact of inventive genius with no identified links to other technology or history: "The steam engine had no precedent … [it] sprang into sudden existence, like Minerva from the brain of Jupiter)" (Basalla, 1988, p. 35).

In contrast, the recognition that any new technology is a combination of pre-existing technology suggests that any new technology is *networked* to a large range of other technologies, where creators draw extensively from available technologies in the lifeworld. Table 3.3. offers examples of particular technologies that have been described this way – not as unique creations delivered from the mind of a single individual, but as technologies that are full of component technologies and which come from a variety of wider available technologies.

Table 3.3 Technologies described as combinations

Technology	Reliance on history
Jet engine	"The turbojet is heir to two centuries of turbine development, including water turbines, turbine water pumps, steam turbines, internal combustion gas turbines, and piston engine superchargers and turbosuperchargers" (Constant 1980, p. 3). "If you open up a jet engine (or aircraft gas turbine powerplant, to give it its professional name), you find components inside—compressors, turbines, combustion systems. If you open up other technologies that existed before it, you find some of the same components. Inside electrical power generating systems of the early twentieth century were turbines and combustion systems; inside industrial blower units of the same period were compressors" (Arthur, 2009, location 279).
Motor truck	"For example, the internal combustion engine branch was joined with that of the bicycle and horse-drawn carriage to create the automobile branch, which in turn merged with the dray wagon to produce the motor truck" (Basalla, 1988, pp. 138–139).
Word processor	"The word processor is not much of a 'scientific' invention. It hooks up three existing instruments: a typewriter, a display screen, and a fairly elementary computer. But this combination of existing elements has resulted in a genuine innovation that is radically changing office work" (Drucker, 1986, p. 211).
Telegraph	"The telegraph, like the railroads, was a typical nineteenth-century invention in that it was a combination of separate technological inventions that had to be moulded together. Just as the strength of a chain can never be greater than that of its weakest link, the efficiency and reliability of a system can never be greater than that of its weakest component. Long-distance telegraph required many subsequent inventions and improvements, which took decades to complete" (Mokyr, 1990, location 1927).
CAT scanning	"CAT scanning (Trajtenberg, 1990) drew upon X-ray technology, which was already applied in the medical imaging domain, and computer technology, which had been applied to data processing" (Adner & Levinthal, 2002, p. 11-12).
Calculator	"The internal processing elements of the original calculator were manufactured as discrete components that were electrically interconnected in the final design" (Merges & Nelson, 1990, p. 859).
Fibre optics	"Technical change often involves the combination of many knowledge fields and complementary products/services. For instance, the use of fiber optics in telecommunication required the development of laser technology" (Granberg, 1988).

The examples in the table above isn't extensive. Ultimately, it could be argued that with appropriate research any technology could be put in this table. As John Donne proclaimed that no man is an island, and Darwin added that neither is a clam or tulip (Dennett, 1996, p. 121), so is no technology an island either: any technology is connected to and made up of other technology.

As a consequence, when considering how new technologies are formed, the state of available technologies should be viewed as a strong constraint (Basalla, 1988; Clark, 1985, p. 241; Constant, 1980; Gilfillan, 1927; Lipsey et al., 2005). New technologies rely on more than imagination – they rely on the availability and performance of existing technologies. For this reason, different lifeworlds are used to represent how the availability of technologies changes over time, and how, due to growing accumulation, technologies not possible in one lifeworld become possible in a later one. The prehistory lifeworld describes the time before it is possible to create a technology, where the lifeworld does not offer the required accumulative capacity and availability of potential component technologies. There is, however, expected to be some particular activity in the prehistory lifeworld, despite the inability to create the technology in focus.

3.1.3 **Imaginative descriptions of technology**

The prehistory lifeworld identifies that there is likely a time where the lifeworld does not yet offer the capacity to create the technology. The components and conditions to create the technology in focus remain outside the capacity of this lifeworld.

Despite this, humans have a capacity for imagination, and, as a result, it may be possible to identify imaginative descriptions of the technology prior to it being possible to build. The phenomenon, described by Basalla (1988) as "technological visions", describes how prescient individuals can sometimes describe a technology long before there emerges the possibility for its creation. These descriptions may remain imaginative, or individuals may attempt to build, but, in doing so, will fail, revealing a lack of capacity of the lifeworld.

If these predictions are found, however, it is expected that, whilst offering a generalised similarity to the eventual technology, these predictions will be lacking in detail, or have the wrong technological components. Poe, for example, writing in 1844, describes a world that has come to pass with air travel: "The air, as well as the earth and the ocean, has been subdued by science, and will become a common and convenient highway for mankind!" (Poe, 1844). However, Poe suggests this will be achieved by transatlantic hot air balloon travel, not airplane travel. Also, whilst William Gibson is credited with predicting the internet, in reflecting upon the similarity between his concept of cyberspace and the actual internet, Gibson identifies that they have little in common. For example, Gibson notes that in *Neuromancer* phone booths are used, with Gibson identifying that he did not envisage smartphones or anything similar to it at all, and this appears common in science fiction (Gibson, 2014; Bassett, Steinmueller & Vos, 2013). It is expected that these imaginative descriptions will not enact the technology or provide direction towards its achievement.

The recognition of constraints has also emerged in the technology literature. The concept of timelags represents this, with Ogburn (1922) identifying that to create a technology, imagination must work within and to the constraints of the technology of the time: “The cave man, had he the ability of a modern genius, could not have invented the steam engine, living as he did on the plane of culture existing during the last ice age” (Ogburn, 1922, p. 34; see also Jewkes, 1958, pp. 28-–29). Freeman and Soete (1997) more recently make the same claim that, “[even if] the idea has clicked in the mind of an inventor or entrepreneur, there’s still a long way to go before it becomes a successful innovation, in our sense of the term. Rayon was ‘invented’ 200 years before it was innovated, the computer at least a century before, and aeroplanes even earlier” (Freeman & Soete, 1997, location 4300).

In this prehistory lifeworld, when component technologies do not yet exist or are in an adolescent state, whilst imaginative description may emerge, attempts at innovation fail. The effect of preceding history is strong enough to constrain the potential of a particular idea to become a technology until such time as the capacity of technology “catches up” (Jewkes, 1958, p. 20). Without capable components many ideas lay dormant for extended periods, before such time as components arrive.

This represents what will be explored and discussed with respect to the technology of the prehistory lifeworld.

3.1.4 **Parallel technology**

Along with the features of the prehistory lifeworld discussed above which relate to the capacity to build a new technology, overlaid in this same lifeworld are conditions of a mature parallel technology that later will have to compete with the emergence of the new technology. In the prehistory lifeworld the pre-existing technology is expected to be in a strong state, with strong socioeconomic alignment. This will be explored below.

Today, the cultural base of a technology is large (Arthur, 2009), and, depending on the maturity of the industry in focus, there may be a history of discontinuities where there is a recognisable sequence of technologies that, whilst based around a particular technology (Anderson & Tushman, 1990; Tushman & Anderson, 1986), offer a similar form of consumer value. An example is the progression of airplanes from propeller piston engines to turbine jet engines (Constant, 1980). In isolation each technology is discontinuous; in sequence they represent a lineage of tools for flight. Another example for gaming: Pinball arcade games, to video games, to smartphone games, to perhaps soon virtual reality gaming, in many ways represent a lineage, albeit one full of discontinuous innovation.

The significance of this is that for a new technology to be widely adopted, it must also cause the discontinued adoption of an existing technology. The prevalence of this has led to terms such as disruption (Christensen, 1997) which describe how world leading companies capitulate to new technologies. As a result, overlaid in the same environment for the new technology, are parallel conditions related to an existing one. These conditions are often the inverse, and a prehistory lifeworld for a new technology represents the mature lifeworld of an existing one.

There is a need to describe how a new technology first emerges, competes with, and then supersedes an existing technology, where the lifeworld offers a different likelihood of innovation to each technology. As the lifeworld surrounding these technologies changes, so too does the likelihood and possibility of innovation for both. In the prehistory lifeworld, there is recognition that conditions are conducive to the older technology being a strong innovation with a strong socioeconomic alignment. This technology may be in a state of “normal science”, where effort is applied to its incremental improvement and extending this as far as possible (Abernathy & Utterback, 1978; Kuhn, 1962). At this stage, whilst there is not yet any threat from the new technology, it is useful to identify this pre-existing parallel technology.

3.1.5 **Summary of prehistory lifeworld**

The prehistory lifeworld describes a time before the technology is possible. The lifeworld does not offer the requisite component technologies required to create the technology in focus. Despite this, in this lifeworld there are expected to be imaginative descriptions of the technology, and within the lifeworld, there exists a parallel technology in a strong state of maturity.

Imaginative descriptions and parallel technologies to mark this prehistory lifeworld will be explored in the case study. A number of markers summarising these concepts, and which will be used to explore the case study, are provided in Table 3.4:

Table 3.4 Summary of markers for the Prehistory lifeworld

Marker 1	It may be possible to identify imaginative descriptions of the technology.

Marker 2	These imaginative descriptions reveal an inability to create the technology.
Marker 3	There may be a history of discontinuities of similar forms of parallel technologies.
Marker 4	There is expected to be a particularly strong parallel technology that the new technology will later compete against.

3.2 Establishment lifeworld

The second lifeworld is described as the establishment lifeworld. In the establishment lifeworld, the first products are offered, establishing the domain in focus. Compared to the prehistory lifeworld, accumulation has advanced to a point where there are now components that make it possible to create the technology in focus. Despite the emergence of these technologies, they are not expected to achieve significant innovation due to adolescence of technology, lacking performance, and the strength of parallel technologies.

The literature review section on combination identified that each new technology can be viewed as a combination. Extending this, the previous prehistory lifeworld literature identified that each new technology should be viewed as a combination of wider components, where these components must exist prior to being used in the technology in focus. This frames the creation of novel things as a process of applied familiarity, taking what already exists in the lifeworld, and recombining it in new ways to create new things (technologies, concepts, knowledge).

The description of this next establishment lifeworld will focus on the dynamics of the lifeworld, and how the conditions to create the technology emerge as a result of accumulation. The establishment of a technology is dependent upon the availability of components, and it is expected that, for a successful creation of technology, accumulation at one point offers conditions to create the technology that was previously not possible in the prehistory lifeworld. How these conditions emerge through accumulation will be a focus in describing the establishment lifeworld.

There are two ways to describe how the lifeworld accumulates enabling conditions for the creation of a new technology: accumulation as a result of new technologies, and accumulation as a result of incremental improvement in existing technologies. These will both be discussed below.

3.2.1 **Accumulation via new technologies**

One way that the capacity of technology advances is through accumulation through new technologies. Each new technology, whilst being a combination of existing technology, also itself becomes a potential component in further combinations. The combustion engine, for example, can be viewed as a technology and a combination of preceding components, such as steel, petroleum, etc., – but in becoming available as a technology, the combustion engine could then be used itself as a component in new technologies, such as motor cars or tractors. In this way, the material base of the lifeworld is ever expanding (Arthur, 2009), with each new combination both drawing from and adding new capacities.

3.2.2 **Incremental improvement creating combination and exaptation opportunities**

The second way accumulation builds to create enabling conditions for the creation of a new technology is through incremental innovation in existing technologies. Incremental innovation is commonly viewed in the technology literature as the powerful force of improvement of existing technologies (Dosi, 1982, 1988; Enos, 1962; Nelson & Winter, 1977; Rosenberg, 1994). Technology arrives as initially crude and adolescent, but over time develops a more reliable and effective performance capacity as effort is applied to improve the technology (Dosi, 1982; Hughes, 1983, p. 43; Lispey et al., 2005, location 1573; Nelson & Winter, 1977; Perez, 2009; Rosenberg, 2005; Schumpeter, 1942, location 1837). Exploring this concept deeply, there is recognition that technologies have trajectories (Dosi, 1982, 1988; Nelson & Winter, 1982) where, as a result of incremental improvement, the characteristics and performance of a technology dramatically differ over time. Viewing a technology at different times (t0-t1), it will be possible to identify clear differences in exhibited capacity, where the technology itself becomes powerful and capable of things at previous times not possible.

Incremental improvement has been acknowledged to be the bulk of the work of innovation (Bessant, 1992; Sahal, 1981, p. 37). It represents the “slow plodding progress” of development (Rosenberg, 1983, p. 64) that over time enables dramatic change in performance. Whilst not recognised with the same fervour as dramatic innovative breakthroughs, and often viewed as inconspicuous or undervalued (Enos 1962, p. 180; Landau & Rosenberg, 1986, p. 282), the effects of incremental innovation are extremely powerful (Rosenberg, 1983, p. 64). For example, forecasting the future adoption of the cellphone at its inception in 1983, AT&T predicted that by 1999 subscriptions might reach one million (Mowery & Rosenberg, 1998, location 942). In reality, by 2000 US subscriptions had reached approximately 92 million in the U.S. and 500 million worldwide (Lehrer, Green, & Stock, 2011). The discrepancy between the forecast and the outcome was attributed to the underestimation of the effect of incremental improvement on the cost of the device (Mowery & Rosenberg, 1998, location 942) with the cost of a cellphone decreasing from $3,000 to approximately $200 as a result of improvements in performance of components in this time (Hausman, 1999).

Incremental improvement is important to the concept of the lifeworld, as existing technologies may reach thresholds in performance that enable new combinations. Perez (2002) discusses this concept, suggesting that the emergence of new powerful technologies (techno-economic paradigms in her language) are based not only on the presence of new components but importantly on the attainment of new performance in existing technologies. Perez suggests that it was not only the presence of steel that lead to the industrial revolution, but *reliable access* to *cheap steel*. It was not only microelectronics that led to a computing paradigm but *cheap* microelectronics that exhibited reliable cost and performance improvement (Perez, 2002; see also Freeman, 1991, p. 83). Cost is one performance criteria, but others may be weight, size, memory capacity, efficiency, and so forth. Other researchers have made similar recognitions (see Table 3.5).

Table 3.5 Example of required performance of components

Technology	**Example of required performance of components**
Steam engine	"The compound steam engine had to await cheap, high quality steel. Higher pressures (and therefore greater fuel economy) in power generation required high-strength, heat resistant alloy steels. Hard alloy steels, in turn, were of limited usefulness until appropriate new machine tooling methods were developed for working them" (Rosenberg, 1983, p. 62).
Bicycle	"Another new consumer product which owed its rapid growth in the 1890s partly to cheap quality steel was the bicycle. The techniques used for their manufacture before the 1920s were not yet Fordist mass production techniques, but they were certainly high volume production, taking advantage of the new potential of steel intensive products" (Freeman & Soete, 1997, location 1370).

In this way, it is possible to suggest that the lifeworld at any given time is made up of technologies that have particular performance characteristics, which exist in particular niches based on these characteristics (Levinthal, 1998). Due to incremental innovation in these technologies, these same technologies at another time may have different performance capacities that enable new combinations that utilise the technology.

Levinthal (1998) and Adner and Levinthal (2002) explore this with the concept of exaptation, discussed in the literature review, which identifies that often the establishment of radical new technology can be achieved not necessarily with new technology but, instead, the application of an existing technology to an entirely different domain:

> A technology undergoes a process of lineage evolutionary development within a given domain of application. At some juncture, that technology, or possibly set of technologies, is applied to a new domain of application. (Levinthal, 1998, p. 223)

With respect to the enabling conditions for a particular technology, exaptation would suggest it is the performance capability of technologies of other domains that at some point leads to the creation of a new technology. As these existing technologies incrementally improve, they may reach a performance "threshold" (inflection point, tipping point) that creates an exaptation opportunity for the creation of new combinations.

The capacity of these technologies is viewed as dynamic, and at any time it is their current capacity that defines what types of combination they can be used for. Recognising the role of exaptation, it is possible to suggest that as the capacity of these technologies changes, they enable new exaptation opportunities, being applied to new purposes far distant from their original or previous roles. For example, whilst the first computers were used as a military tool to calculate firing tables (Basalla, 1988, p. 141), they have gone on to be used in a great deal of industries that are distant to this original use. And the availability of electricity in homes, originally as a source of lighting, was soon put to a different use, with electric motors becoming a key technology of the kitchen appliance industry (Hughes, 1983). Put differently, the capacity to create new radical technologies "grows" out of these existing technologies as their performance expands, rather than being the result of distinct unique attempts at innovation. This further advances the recognition of combination and exaptation as critical markers of new creation, and it also leads to the recognition of the role of incremental improvement in existing technologies as a key characteristic of what creates the establishment lifeworld, where new technology is possible that previously was not.

The discussion of the prehistory lifeworld identified that there may exist a strong parallel technology offering a similar form of value to the one about to be created. Exaptation would suggest that the new technology will not emerge from the existing industry but, instead, somewhere far removed from it. This might have consequences for how the new technology is viewed by the existing industry, as well as perhaps creating special conditions for the act of insight to link the disparate technology to a new domain of application.

3.2.3 **Summary of establishment lifeworld**

The establishment lifeworld describes the conditions that lead to the creation of a technology. It recognises that new technology is a combination of pre-existing technologies, and that for the technology to be created there must be a build-in capacity in this lifeworld compared to the previous prehistory lifeworld. In describing these conditions in the establishment lifeworld, the focus has been on describing how accumulation in available technologies occurs to offer particular enabling conditions for the creation of the new technology. Table 3.6 presents a number of markers summarising the ideas of the establishment lifeworld which will be used to explore the case study.

Table 3.6 Summary of markers for the establishment lifeworld

Marker 1	The domain will be established with the release of a new product.
Marker 2	The new technology can be described as a combination of pre-existing technology.
Marker 3	The component technologies that are utilised will have a traceable history in other domains.
Marker 4	There are some tangible new performance characteristics of these component technologies, represented as “combination thresholds” that make the new technology possible.
Marker 5	The new technologies will emerge as adolescent with limited performance and will now compete against a parallel technology in a stronger state.

3.3 Development lifeworld

The early technologies of the previous establishment lifeworld do not lead to significant innovation immediately. The third lifeworld, marked as the development lifeworld, describes the most dramatic design work of the technology. The technology is initiated as crude, adolescent, and uncertain (Abernathy & Utterback, 1978, p. 42; Clark, 1985, p. 238; Henderson & Clark, 1990, p. 14) but improves through processes marked collectively as development in this lifeworld.

There are three key processes used to describe the development lifeworld. First, there is expected to be a recognisable increase in entrepreneurs offering new products (Klepper, 1996). These products initiate a process of variation and selection, where the selection environment (Nelson & Winter 1982) of the wider lifeworld reveals constraints and limitations of the technology over a number of socioeconomic influences. Second, the technology faces significant competition in this lifeworld. It has now emerged as a distinct technology but remains one of many parallel alternatives, with recognition that there will be pre-existing alternatives with stronger performance and alignment that it must now compete with. With the problems of the technology revealed by trial and error in this lifeworld, the capacity of the technology to achieve innovation fluctuates and remains uncertain. Finally, accumulation in capacity of the lifeworld, discussed previously, continues, offering a larger range of technology with greater levels of performance that weren't previously available. It is likely that there are continued exaptation events that bring new component technologies in the domain into focus.

These concepts will be discussed in detail below.

3.3.1 **New entrants**

There is expected to be a dramatic number of new entries from competitors. Consistent with innovation lifecycle models (Agarwal & Gort, 1996; Jovanovic & MacDonald, 1994; Klepper, 1996; Klepper & Miller, 1995; Maine et al., 2014), the launch of first technologies initiates a wave of new entrants who sense an opportunity for dramatic innovation. Borrowing a metaphor from Jewkes, if the previous establishment lifeworld is where the scent has been picked up, the development lifeworld is where "the hunt is in full cry" (Jewkes, 1958, p. 28).

New entrepreneurs are expected to come from a variety of industries and backgrounds. As described previously, in the establishment lifeworld an exaptation event is expected to establish the technology. If this is the case, then the technology will have a history in an industry that is different from the new application. Using Basalla's (1988) example, the combustion engine was created in the mining industry but was applied to transport, leading to the development of motor cars, with inventors also drawing from the bicycle industry, such that Ford called his first ever car the "Quadricycle" (Doeden, 2007). Cattani's discussion of "pre-speciation" (Cattani, 2006) and O'Reilly and Tushman's (2016) discussion of organisational "ambidexterity" highlight that exaptation events favour some firms over others based on their history of skills and experience. Whilst those who establish the technology in the previous lifeworld may have some unique industry experience or vantage point to identify the combination and exaptation opportunity, once the technology is established in this development lifeworld there is expected to be engagement from entrepreneurs from a wider variety of impacted industries, from those who have experience in the new technology to those who have a history and understand the industry of application.

The large volume of competitors offering products creates a variation and selection process that further develops the technology. These variation and selection processes will be discussed below.

3.3.2 **Variation and selection**

The products offered from the variety of entrants create a process of variation and selection (Clark, 1985). Each product offered to the market by entrepreneurs can be seen as a hypothesis (Arthur, 1994, p. 407), and, based on feedback from the selection environment (Nelson & Winter, 1982), entrepreneurs refine their understanding of the performance of different designs. An understanding of better performing designs accumulates probabilistically rather than deterministically, and even entrepreneurial failure, which is expected to be common during development (Arthur, 1994, p. 407; Garud et al., 2013, p. 777), offers valuable feedback to the marketplace with respect to uncovering critical problems in design, referred to as "bottlenecks" (Clark, 1985; Gatignon, Tushman, Smith & Anderson, 2002, p. 1106) or "reverse salient" (Hughes, 1983). These problems or limitations of particular types of design become more obvious with a greater amount of feedback (Simon, 1962, p. 472).

It is expected that selection does not only reveal problems at a technical level but socioeconomic constraints as well. For the technology to achieve innovation there is a recognition of socioeconomic factors within the lifeworld having an influence on the development and design of the technology (Campbell, 1969; Constant, 1980; Dosi, 1982, 1988; Geels, 2004; Geels & Schot, 2007; Kemp, Rip, & Schot, 2001; Simon, 1962). These factors are not passive receivers of new technology in the sense that they accept whatever characteristics are presented by the technology, but, instead, they themselves actively contribute to the design (Sahal, 1981) and selection. There are a number of these factors within the lifeworld that are engaged and have a direct influence on the design of products.

– *Component level variation and feedback*

The products of the establishment lifeworld offer a technical design, and whilst this is expected to be popular with entrepreneurs, it is also expected that entrepreneurs will explore and experiment with different types of components and configurations within the technology. In the early stages of the automobile industry, for example, cars were offered with gasoline, electricity, and steam engines, as well as wood and aluminium bodies (Abernathy & Utterback, 1978; Henderson & Clark, 1990, p. 14). In the design of steamboats, there was a choice between wood and iron hulls (Gillfillan, 1935), and in the early stage of railways there were a number of varied track width designs (Tushman & Anderson, 1986). This type of variation appears common in the early stages of the design of a technology (Geels, 2002, 2005).

– *Consumer feedback*

Consumers play a central role in the development and configuration of technology. The technology is not delivered readymade with meaning articulated prior to consumer use (Tuomi, 2002, p. 9), but instead consumers actively define and shape its meaning (Fischer, 1992, p. 84-85). The role of consumers has been recognised as so central to the development of technology that their role has been acknowledged to be the most important: "The single measure which discriminated most clearly between success and failure was 'user needs understood'" (Freeman & Soete, 1997, location 4501). As a consequence, much of the design task relates to understanding user needs and translating these into the design of the artefact, ensuring the design offers particular features that appeal to user preference.

The reliance on the consumers to shape the technology leads to a paradox in this development stage. The technology is adolescent, and its performance is limited or not entirely reliable, but it still requires consumer input to be shaped into something useful. For example, the early performance of automobiles (described as horseless carriages) was bad enough to limit widespread adoption (Levinthal, 1998, p. 221), despite the fact that the performance of the automobile would improve if it were widely adopted. If the technology does not achieve minimal thresholds of functionality (Basalla, 1988; Levinthal, 1998) for mass markets, the technology is not likely to be selected in these markets. For these mass markets, the technology itself may be too expensive, too operationally complex, or too unreliable to offer enough value in comparison to pre-existing technologies.

Despite the technology not meeting performance requirements of mass markets, meaning and configuration of the technology remain something that must come from consumers (Geels, 2002), and their feedback is central to reducing uncertainty about the configuration of the technology (Pinch & Bijker, 1984). This paradox is addressed by the development of the product in niche markets (Christensen, 1997; Rip & Kemp, 1998; Geels & Schot, 2007). Niche consumer markets are not simply early adopters of a mature technology (Rogers, 1995), but instead niche markets actively develop the technology (Clark, 1985, p. 246; Fichman, 2000). Despite having incomplete performance, the niche market application can utilise the current performance offered in the technology at this early stage, whilst navigating the limitations or missing features. Early automobiles, for example, were used primarily as a recreational technology for the rich (Basalla, 1988) and public entertainment in the form of motor races (Colt, 1996). Pneumatic air-filled tyres are another example – they were first adopted by bicycle racers before eventually migrating to mass markets as the performance (cost, durability) of designs improved (Bijker, 1997).

The recognition of the importance of niche markets highlights the expectations that consumers place on performance. Preference with respect to retail cost, usability, branding, and consumer learning curve (Perez & Soete, 1988, pp. 468–469) all represent criteria that can impact the perceived value of a technology (Rogers, 1995; Bijker, 1997). Each new product offered to the market should be seen as a hypothesis that both reveals and shapes this criterion. To be successful, entrepreneurs must understand with precision what that market has a value preference for and embed this into their product, even when the preference itself may not at first appear entirely rational (Cusumano et al., 1992). For example, the persistence of popularity of the QWERTY keyboard layout, despite there being clearly superior design alternatives (such as the DVORAK design, which offers faster typing efficiency), is a case where entrepreneurs in the computer market must offer a less than optimal technological feature in order to satisfy consumer value criteria (Anderson & Tushman, 1990; David, 1985). Those entrepreneurs that have attempted to optimise for other levels and disregard this consumer preference have failed, including Dvorak himself (David, 1985; Liebowitz & Margolis, 1990; Utterback, 1996). The many new products in this development lifeworld reveal and shape these consumer criteria with respect to designs that deliver the most consumer value.

– *Complementary alignment and feedback*

The technology does not exist in isolation but is dependent upon a range of complementary technologies, suppliers, and distribution channels (Rosenberg, 1983, p. 59). In this lifeworld, development also extends to the identification and alignment of these complementarities. The performance of the technology is dependent on entrepreneurs' ability to coordinate these complementarities. The automobile, for example, as Unruh (2000, p. 822) notes, was dependent upon industry coordination of complementarities such as petroleum, glass, rubber and steel. Externally, the value of the automobile was also dependent upon the coordination of industries (and governments) related to availability and production of roads – asphalt, concrete, and steel industries, and subsequent complementarities such as service stations, repair workshops, and, at an even more distant level, motels and drive-in movie theatres (Flink, 1988). This process of emergence and configuration of these complementarities is difficult, but one that is central to the performance of a particular technology (Geels, 2002, p. 1270). In the development lifeworld, the complementarities relevant to the new technology are likely to either be in their own adolescent state or, if in a mature state, likely to be coordinated and configured around an alternative technology. In these conditions, the new technology will have to overcome the sting of illegitimacy (Garud et al., 2013) to disrupt these established relationships and form new ones.

– *Cultural feedback*

A technology is embedded within a culture that has a direct impact upon its value and configuration. The use of the term "culture" here is consistent with what is introduced by Garud et al. (2013, p. 797) and broadly represents the economic, political, and legal environment in which the technology is placed. These conditions have an impact on the design criteria and value of the technology.

Garud et al. (2013, p. 797) use the example of Bikram Yoga to highlight the difference that culture can have on the configuration of a technology. In the U.S. copyright was granted for the postures of Bikram Yoga, which subsequently was exploitable for profit by the copyright holder in these conditions. In India, however, the same Yoga postures have been practiced for centuries, and any claim for personal ownership would be rejected. A similar concept was identified by Basalla (1988) with respect to the renouncement of gun weaponry in Japanese military culture in the early 19th century due to the symbolic artistic and cultural values imbued in sword weaponry of the samurai warrior class (Basalla, 1988, pp. 188–189). This highlights how the cultural context actively shapes the political and legal environment in which the technology is embedded, and that "innovation is culturally induced" (Garud et al., 2013). Consistent with this, there are expected to be particular unique cultural factors that manifest as a result of the technology and that influence its development, where the new technology may not initially align with existing cultural conditions and may require adjustment to these conditions or to the technology itself.

3.3.3 **Summary of the variation and selection work**

The various products as part of this variation and selection process reveal and induce feedback from the lifeworld across these factors. This feedback reveals "reverse salient" (Hughes 1983) of design across these multiple criteria, including all technological and socioeconomic factors.

The puzzle-solving activity (Anderson & Tushman, 1990, p. 605; Kuhn, 1962; Wooten & Ulrich, 2016) of this development creates an accumulating understanding of better performing designs. This understanding does not simply arrive all at once but unfolds over time (Arthur, 2009; Brown & Eisenhardt, 1998; Schumpeter, 1942, location 1837; Van de Ven & Poole, 1995), where both the lifeworld and the internal technology (as a combination of components) develop and shift to find alignment. It takes time to engage the lifeworld, establish and coordinate complementarities, find agreement regarding standardisation of components, identify and address problems of design or performance across levels (as reverse salients; Hughes, 1983), and gain legitimacy in comparison to competing technologies.

Whilst variation is not constrained, and entrepreneurs can offer combinations of any configuration, previous selections offer feedback about what is effective and what can be discarded (Arthur, 1994, p 407), with this being used to create more complex designs. This has been referred to as the Baldwin effect (Baldwin, 1896) in biology, where successfully selected designs are often imitated by others seeking selection (Dennett, 1996, location 1565), algorithmic compressibility (Tsoukas, 2004, location 1715), or accumulation (Usher, 1954). The development process becomes one of *selective* trial and error (Simon, 1962, p. 472), where the best designs accumulate probabilistically rather than deterministically (Van de Ven et al., 1999; Rosenberg, 1983). Through selective trial and error, many paths of the maze are explored but a direction results, driven by the emergence of higher performing designs that are then utilised by entrepreneurs for the next stage of development (Simon, 1962, p. 472). This leads to an accumulated understanding of both the problems of configuration and appreciation for demonstrated and expected performance (Dosi, 1982; Perez, 2009; Usher,1954; Van de Ven et al., 1999).

Competition

Due to the adolescence of the technology with limited performance and the process of trial and error in this development lifeworld, which further reveal problems and limitations of the technology, expectations of the innovative potential of the technology may fluctuate. The emergence of the technology in the establishment lifeworld might bring with it unbridled enthusiasm for it as an innovative technology of the future, but in this development lifeworld, this potential is replaced with failure, problems, and limitation as the technology struggles towards performance. Whilst capacity is developing, the innovative capacity may no longer be clear, and there may be newly developed uncertainty regarding the technology.

The uncertainty regarding the innovative potential of the technology will be exacerbated by parallel technology. The technology in focus will not have an exclusive path to innovation. It is competing for selection against other parallel technologies, and there is expected to be a pre-existing technology in a mature state that continues to have strong momentum (Dosi, 1982; Hughes, 1969; Milgrom, Qian & Roberts, 1991). The embeddedness and reliable performance of this existing technology has the capacity to slow down development and adoption of the new technology. The existing technology has the advantage of lock-in and path dependency (Arthur, 1989), which is expected to demonstrate significant resistance to the new technology, regardless of its performance and development. In this way, the consistent adoption of a mature technology represents a rational choice, but one which later can prove to be the source of disruption (Christensen, 1997).

Ongoing accumulation

Amidst this development process, the lifeworld continues to accumulate new capacities. The accumulation process that was discussed in the prehistory and establishment lifeworlds continues in this one. Through both new combinations and incremental innovation, new technologies and new performance become available in the lifeworld that weren't previously possible. As a result of this continuing accumulating capacity, it is expected that there will be further examples of new exaptation or combination as new capacities are drawn into the domain from the external lifeworld. These new capacities may be drawn in as solutions to emerging identified reverse salient in existing designs.

3.3.4 **Summary of development lifeworld**

The development lifeworld describes the difficult work to develop the technology. The technology emerges as adolescent but with the potential for innovation in the establishment lifeworld. In this development lifeworld, spurred by a large number of entrepreneurs who create a process of variation and selection, problems of the technology are revealed, and the potential of the technology to achieve innovation remains uncertain. There is not yet any dominant product, with available alternatives having a range of limitations or problems that inhibit adoption, particularly in light of parallel technologies that have more reliable performance. The variation and selection process of this lifeworld is where the bulk of the work of future innovation is done, and where the enabling conditions of dramatic innovation are built, but attempts during this development lifeworld are often marked by failure, and innovation remains elusive. The products of this lifeworld accumulate a better understanding of optimum design characteristics that will be capitalised on in the next lifeworld. Accumulation also continues as the lifeworld offers new levels of performance and new types of technologies that were not possible previously or not available. The markers to summarise the discussion of this lifeworld are offered in Table 3.7:

Table 3.7 Summary of makers for the Establishment lifeworld

Marker 1	There is a dramatic number of new competitors, from a variety of industries, offering new products around the new technology.
Marker 2	These new products initiate a variation and selection process, which reveals problems and limitations with the new technology across socioeconomic criteria of the lifeworld.

Marker 3	The new technology represents one of many alternative pathways to innovation and must compete against parallel technologies. Due to emerging limitations of the technology, its recognition as a potential innovation will fluctuate, particularly compared to established technology that offers reliable performance.
Marker 4	Accumulation in capacity of the lifeworld continues, and this creates further opportunities for exaptation and combination, with components of greater capacity becoming available.

3.4 Innovation lifeworld

The fourth and final lifeworld is when dramatic innovation is achieved. A new design emerges in this fourth lifeworld to achieve dramatic innovation.

The dominant design is a single product that comes to achieve widespread adoption, capturing the vast majority of value of the innovation of the entire domain, having the effect of disrupting many previous entrepreneurs from the domain (Abernathy & Utterback, 1979; Sahal, 1981). Whilst relying on the accumulated learning and capacity of the previous lifeworld, which provides many conditions critical to the creation of the dominant design, the dominant design is an extension of this, and requires new insight and advance – what Usher refers to as the task of “critical revision and mastery” (Usher, 1954). The design may emerge as a result of furthering accumulation where the lifeworld offers new components or new performance not possible at previous times. This design, once released, emerges amidst uncertainty and a great deal of alternative designs, but as a process will establish dominance over the entire class of products, to then become recognised as a dramatic innovation becoming difficult to dislodge.

3.4.1 **Emergence of a dominant design**

The recognition of a dominant design is a common stage in process models of technological evolution (Anderson & Tushman, 1990, p. 613; Dosi, 1982; Nelson & Winter, 1982; Sahal, 1981; Utterback & Abernathy, 1979). Dominant designs have been identified in a range of different industries, emerging after a time of intense competition. Dominant designs have been identified in industries such as airplane design (the Douglass DC 3 airplane design; Abernathy & Utterback, 1978; Nelson & Winter, 1982), automobiles (the Model T Ford; Teece, 1986, p. 288), computing (the IBM Personal Computer; Suárez & Utterback, 1995), bicycles (the safety bike design; Bijker, 1997), synthetic dyes (Van den Belt & Rip, 1987), machine tools (Noble, 1986), photolithography (Henderson & Clark, 1990), and typewriters (David, 1985), just to name a few. An example description is that of the Underwood Model 5 typewriter, which was an early dominant design in typewriter technology. It became the standard configuration of typewriters:

> With its single QWERTY keyboard, visible type, tab feature, shift-key capitalisation, carriage cylinder, and so forth, this particular design brought together a number of market-proven innovations into a single machine and very quickly came to command the typewriter industry. It remained the dominant design for decades, defining how the typewriter was supposed to look and operate in the minds of both typists and other typewriter producers. (Utterback, 1996, pp. 24–25)

3.4.2 **How dominant designs are formed**

Why a particular product becomes a dominant design when previous products have failed appears more complicated than simply ascribing it to be a superior technological product. Technologically, whilst the dominant design achieves uncommon success, it is expected to rely on many common components also utilised by competitors (Abernathy & Utterback, 1978; David, 1985; Utterback, 1996, p. 24). Despite using many common components, the dominant design will be unique as a combination, and will deliver innovation performance previously unseen in the domain (David 1985).

Whilst relying on many standard components, the design may also make use of continuing accumulation – there may be new components available in the lifeworld, or continued incremental improvement in technologies, that offer new performance that at previous times wasn't possible. This may manifest in continuing examples of exaptation where new components are drawn from the lifeworld that have a history in alternative product categories. This accumulation may be the source of a new form of performance that now enables a new design that addresses problems and limitations with previous designs.

Beyond technological components, the success of the dominant design is attributable to its performance across non-technological factors. Acknowledging that innovation is influenced by a range of technological, economic, social, and cultural conditions discussed in the previous lifeworld, research has identified that often dominant designs emerge as a result of being the most effective design across these multiple criteria, rather than simply being the most advanced technology (Cowan, 1990; David, 1985; David & Bunn, 1988; Hughes, 1983; Murmann & Frenken, 2006, p. 936; Tushman & Rosenkopf, 1992). For example, in discussing the Douglass DC-3 airplane that became a dominant design, Abernathy and Utterback point out that it was the best at balancing a range of criteria, rather than being optimised for any single criterion in isolation: “It was not the largest, or fastest, or longest-range aircraft, it was the most economical large, fast plane, able to fly long distances” (Abernathy & Utterback, 1978, p. 43). This appears important to the concept of a dominant design, and it is expected that there will be identifiable trade-offs made to achieve optimum full alignment performance as opposed to optimisation on one criterion in isolation.

3.4.3 **Dominant design as a process**

The achievement of a dominant design is recognised as a process rather than an event. This has some particular effects with respect to recognition, competition, and its own incremental improvement over time.

When the product is first released, its innovative capacity remains initially contestable due to its use of a large number of common components. However, over time, consumer adoption is follows a similar sequence of Rogers’ diffusion model (1995) proving the technology to be a dominant design, leading to its recognition as a powerful innovation.

There is expected to be fierce competition before the emergence of a dominant design, and with respect to which entrepreneur capitalises on this, there are expected to be particular characteristics that allow for certain firms to have an advantage (O’Reilly & Tushman, 2016). Equally, the role of co-specialised assets (Teece, 1998) becomes important and can be a source of advantage for particular entrepreneurs. Co-specialised assets are defined as those assets of an individual company, such as control of market channels, brand image, and product range inducing switching costs (Utterback, 1996, pp. 27–28), that offer an advantage in contrast to other companies offering the same product. For example, in analysing why IBM became the dominant design for the personal computer market, Utterback (1996, p. 27-28) identifies that whilst there were many PCs on the market, “to the buying public, the name IBM had tremendous brand value; as a huge firm, its entry meant that replacement parts and service would be available and that applications software would begin to appear, encouraged by industry standards that would conform to IBM’s machine”. Co-specialised assets are expected to play a role in entrepreneurial competition for a dominant design.

The emergence of a dominant design has a dramatic effect on competition, and there is expected to be a shakeout over time as a large volume of entrepreneurs exit the market due to a lack of consumer response to their products (Agarwal & Gort, 1996; Horvath et al., 2001; Klepper, 1996; Klepper & Miller, 1995). Those that remain have a positive effect on efficiency (Perez, 2002), by imitating features of the dominant design or looking to service niche audiences with different features.

The dominant design does not also remain static after it is first released. Instead, it is expected that the incremental innovation will improve the dominant design over time. Whilst the core configuration will remain unchanged, it is expected that incremental innovation will change the capacity of the dominant design after its release (Teece, 1986, p. 288). For example, after the lightbulb was released, its performance continued to be dramatically improved as an effect of ongoing incremental innovation: better metal alloys for the filament, coiling of filaments, frosting glass options, along with a dramatic decrease in retail price, were all exhibited improvements (Abernathy & Utterback, 1978, p. 43). It is expected that the incremental innovation process will be reflected in a series of price or performance improvements of the dominant design that occur after its release.

These improvements, and what becomes almost default adoption of the product by widespread consumers, makes the design “difficult to dislodge” (Anderson & Tushman, 1990, p. 614), and, after reaching this state of maturity, the product will only become susceptible under the pressure of a new parallel technology (Christensen, 1997).

3.4.4 **Summary of the innovation lifeworld**

The final lifeworld discussed is when a dominant design emerges to become a dramatic innovation, eclipsing all previous attempts. This dominant design is a unique combination, but one which relies on common components of other products, as well as new components offering performance not previously available. Utilising the accumulating selection feedback from products released in the development lifeworld, the configuration of the dominant design addresses problems and outperforms other designs over multiple socioeconomic criteria.

The dominance of this product emerges as a process over time, and whilst performance is initially uncertain, with increasing and then dramatic adoption the product becomes recognised as a powerful innovation. As this dominance is established, it has an effect on competition, with a large shakeout of entrants and a movement towards imitation.

Once this dominant product emerges, it becomes further improved through incremental innovation, which further makes the design difficult to dislodge. The development process of the product is complete, and it only becomes susceptible to a new competing parallel technology. The markers to summarise the discussion of this lifeworld are offered in the table below:

Table 3.8 Summary of markers for the innovation lifeworld

Marker 1	A new product will be released which becomes recognisable as a dominant design.
Marker 2	The design delivers superior performance by using both common and new components in a unique combination, as well as being more effectively configured across wider socioeconomic criteria.
Marker 3	The new design becomes successful as a process. Its performance is initially contestable, but over time dramatic adoption proves it to be a powerful innovation.
Marker 4	The design has a significant impact on competition. The successful entrepreneur will capture the majority of value of innovation for the entire domain, and over time the product proves difficult to dislodge. Competitors leave the market due to failed attempts or offer products that imitate the dominant design or are designed for niche audiences.

3.5 Chapter summary

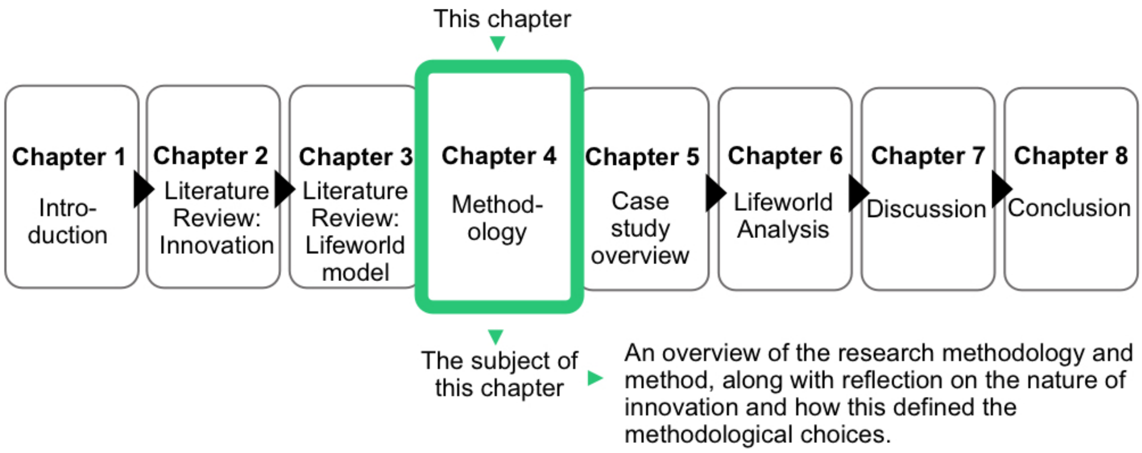
The lifeworld model presented in this chapter is an attempt to recognise conditions outside of and surrounding an idea that have a direct impact on the likelihood of its achievement of innovation. This model chapter provided a description of four alternative lifeworlds – sets of conditions that those attempting to create innovation face. These four lifeworlds describe the process of development of a particular idea from impossible to dominant world-changing innovation, recognising that the potential to create innovation is not evenly distributed but instead emerges briefly, when the lifeworld offers a moment of kairos (Sipiora & Baumlin 2012), viewed as the availability of powerful enabling conditions. The table below is a summary of the four alternative lifeworlds along with a brief summary of the markers of each lifeworld as presented in this chapter.

Prehistory lifeworld	The idea may emerge for the technology, but the lifeworld is characterised by inadequate conditions to create it. As a consequence, the technology remains one limited to imaginative prediction, and markers for this lifeworld relate to this. At the same time as these imaginative predictions emerge, there is likely an alternative parallel technology in a powerful state that will later compete against the technology in focus.

Establishment lifeworld	The lifeworld offers enabling conditions for the creation of the technology in focus. Markers relate to the formation of the new technology, with reference to combination and exaptation. Despite a new technology being created, it's performance is limited.
Development lifeworld	The technology becomes a recognised technology of potential. Markers focus on the large volume of new entrants which initiate a large amount of trial and error in product design. This trial and error reveals innovation is difficult, with a range of socioeconomic design criteria emerging.
Innovation lifeworld	The problems that limited innovation previously are overcome with a product that achieves dramatic innovation. Markers relate to the emerge of a dominant design that captures the majority of value of innovation, resulting in imitation from competitors, and a large shake out of other companies.

Chapter 4

Methodology



4.0 Introduction

This chapter provides an overview of the methodology of this study. With the research question concerned with the role fo the environment impacting the nature of a specific technological innovation over time, this research is process research, and this will be explored and explained in this chapter.

A summary of the research methodology of this study is presented as follows. This is a single case study of digital music player technology, with the end boundary condition of 31 December 2007. Using extensive secondary documentation (over 4,000 published articles) and archival data (45 hours of secondary interviews and keynote presentation video footage), triangulated with 17 one-on-one semi-structured interviews with recognised protagonists and experts (over 20 hours of interview recording), an event history narrative of the development process of digital music player technology has been produced. This event history narrative is extensive and spans events from the 11th century up to 31 December 2007, but the major focus of this event history narrative is January 1995 to December 2007. A summary of this narrative is provided in the next chapter, followed by the findings chapter, which maps this history against the lifeworld model to explore the research questions.

This chapter will provide an overview of this process methodology, providing both the epistemological and ontological foundations of this study, a description of the case study, a description of data and collection methods, and a description of analysis methods employed. It will begin with a brief discussion of the nature of innovation and the impact upon methodological decisions.

4.1 Philosophy of innovation

There are some fundamental characteristics of innovation that make it a difficult phenomenon to research, and represent a broad collection of epistemological and ontological issues. Before moving on to discuss the particular methodology of this research, the following section will explore some of these characteristics of innovation, reflecting upon how they impact methodological tendencies in the innovation literature. This will provide context for the methodological choices of this research.

4.1.1 **Problem of abstraction**

Innovation research is complicated due to the observational difficulty of innovation. Innovation is an abstract characteristic, which means that comparison between innovations is difficult. The airplane and the telephone, for example, look nothing alike and are used for purposes that are nothing alike, yet both have been described as innovation (Constant, 1980; Fischer, 1992). The same can be said of all innovation – implicitly, every recognised innovation will be unique in some way, different from all others.

This observational uniqueness creates complexity for theory. In contrast to the problems of deduction identified by Popper (1959), where in some cases observational repetition can lead to fragility of conclusions (Taleb, 2012), innovation has the inverse problem. In Popper's famous example, a large volume of recorded observations of white swans led to the conclusion that all swans are white, with science written around this, until this characteristic was proven entirely wrong with a later observation of a black swan (Popper, 1959). In contrast, for innovation each observable case of innovation is different and unique from all other innovations. Using Popper's swan example, it would be as if one swan were red, another didn't have wings, one looked like a frog, and on and on, until the only useful conclusion is that no two swans look the same. Two innovations can be distant dissimilar objects and yet both be classified as innovation.

As a result, to capture the large diversity of all innovation, innovation theory can become very general and abstract. Johannessen, Olsen, and Lumpkin (2001), for example, focus on the concept of "newness" defining innovation as something that hasn't been done before. This concept of newness is abstract enough to represent the many different examples of innovation through history but becomes problematic and subjective in interpretation when attempting to apply this concept to any particular example.

– *The popularity of case study research*

In-depth case study research is a methodological response to this problem. Case study research largely avoids the general in favour of a deep focus on the specific. Rather than seeking abstract generalisations to describe innovation, case study research explores deeply the conditions and characteristics of a particular case. This approach has proved to be powerful, with some of the most seminal references in the innovation literature being examples of case study research. Detailed case studies of steamboats (Gilfillan, 1935), radio (Maclaurin, 1950), electricity supply networks (Hughes, 1983), turbojet design (Constant, 1980), typewriters (David, 1980), bicycles and Bakelite (Bijker, 1997), disk drives (Christensen, 1997), and the innovation process at 3M (Van de Ven, Polley Garud, & Venkataraman, 1999) are samples of a research methodology that has proved powerful to the understanding of innovation and shaped the innovation literature.

4.1.2 **Failed innovation and successful innovation may be similar**

Another complicating characteristic of innovation is that just as two artefacts may have no physical resemblance and both be recognised as innovation, it is possible for two artefacts to be almost identical, sharing a great deal of the same attributes and components, but only one recognised as an innovation.

This creates the risk of innovation research of abduction, whereby theory affirms the success of a particular artefact (Flach & Hadjiantonis, 2013; Magnani, 2003; Peirce & Turrisi, 1997), with little regard for how similar characteristics or actions are found in examples of failure. This has been a direct criticism of the linear model of innovation, which, as described in the literature review, explains successful innovation as the specific actions of the individual who succeeds, with little acknowledgement for others who may have undertaken similar actions and failed.

– *A need to explore failure*

There is a resulting methodological imperative to not isolate successful innovation but, instead, explore innovation success in the context of similar examples of failure. Bijker notes that this hasn't always been the focus of innovation research, which at times has been susceptible to survivorship bias, with a more exclusive focus on success: “Most innovation studies have been carried out by economists looking for the conditions for success in innovation” (Bijker, 1997, p. 21). Response to this has been a strength of the innovation systems perspective, with recognition of innovation as both an individual and collective act (Hekkert et al., 2007). Despite this useful intention, as also mentioned in the literature review, the technological innovation systems level repeats the problems of isolation of the linear model by viewing innovation as something achieved by a particular system with little regard for how this system interacts with its wider environment. There remains a need to explore the context and to capture both failure and success more completely.

4.1.3 **Innovation emerges over time**

The final characteristic of innovation that increases its research difficulty is that innovation is not an obvious characteristic of a particular technology at its inception, but instead innovation emerges over time. A well-documented characteristic of technology is that technologies have trajectories (Dosi, 1983; Freeman & Soete, 1997; Lipsey et al., 2005). Even technologies that prove dramatically innovative first emerge as crude and adolescent at the time of their creation (Rosenberg, 1976). Few would dispute the recognition of electrical lighting as a powerful innovation today, for example, but early in its development the innovativeness of this technology was speculative at best and viewed as unlikely by some due to problems: “Countless other problems plagued the station during the breaking-in period. Current leaked from conductors and junction boxes under the streets” (Hughes, 1983, p. 73). Inversely, the difficult journey from raw technology to innovation is not assured, and, just as there are examples of later world-changing innovations that have not resembled this earlier in their trajectory, there have also been many new technologies birthed as expectant world-changing technologies, only for this to never eventuate. This problem of how innovation changes over time is central to this research and creates some particular methodological issues.

– *The importance of historical research*

The trajectory of innovation makes identifying a potential innovation prospectively or in real time very difficult. An acknowledged problem of selecting a developing innovation is that the outcomes may not yet be obvious or complete. For example, the expansive real time longitudinal innovation research of Van de Ven et al. (1999), which attempted to explore the innovation process at 3M in real time, later required an update to capture events that occurred after the research was complete: “Some innovations being studied did not reach their natural conclusion until 1991 (when they were implemented or terminated). Hence the book was written before we knew the end of the story” (Van de Ven et al., 1999, location 54).

For this reason, historical research is an important methodology of innovation research. Rather than selecting a developing innovation, instead it is common for research to explore a past innovation, where events have already occurred (e.g., Basalla, 1988; Bijker, 1997; Constant, 1980; Hughes, 1983). Methodologically the strength of this method is that it avoids premature conclusions. The weakness though, is the potential for increased unreliability on account of biases of hindsight and historicism (Popper, 1954). The availability of data is critical.

– *Innovation as process*

The recognition of change over time as something critical to the nature of innovation also promotes the particular philosophical and methodological perspective known as process research. Process research explores longitudinal change over time, rather than events or variance at a particular point in time. Process research is focused on capturing the unfolding temporal pattern of events with the view that it is this pattern that represents something fundamental to the nature of innovation (Garud et al., 2013).

Process methodology is central to this research, and prior to a description of specific choices and characteristics of the case study, a brief description of process philosophy will be provided, with particular focus on relevance to this research. This will then be followed by an overview of the case study.

4.2 Philosophy of this research

This research is process research; it is an attempt to explore the sequence of events – a temporal pattern that creates conditions of innovation at certain times. A brief overview of process philosophy and how it is relevant to this research will be described below.

4.2.1 **Ontology – what things are**

Process research describes change as the most essential nature of reality. From this perspective, all things are in flux: “The river is not an object but an ever changing flow; the sun is not a thing, but a flaming fire” (Rescher, 1996, p. 10). Everything can be viewed as its own process of activity and change. This view comes initially from Heraclitus who explored these concepts in antiquity, viewing change as the more important part of objects themselves: “What was cold soon warms, what was wet dries, what was scattered gathers and what was gathered blows apart” (Heraclitus, 2001, location 315). By the 20th century, process became a perspective of pragmatist philosophy and an alternative to objectivism (Tsoukas & Chia, 2002), as authors such as James (1907), Pierce (1965), and Dewey (1909) continued to expand the perspective of reality as fundamentally a process (Van de Ven & Poole, 2005, pp. 2–3).

In the innovation literature, process ontology has been increasingly advocated for (Mohr, 1982; Poole, Holmes, Dooley & Van de Ven, 2000; Van de Ven, 2007; Van de Ven & Poole, 1995), and even previous to this advocacy, whilst not formally described ontologically as process research, process appears as something essential to innovation research. From the earliest theoretical manifestations, by Schumpeter (1939, 1942), Ogburn (1922), and Gilfillan (1945), innovation researchers have offered insight into processes of change (Godin, 2010). Schumpeter, for example, contrasts innovation sharply with static equilibrium models and describes capitalism as a process: “Capitalism then is by nature a form or method of economic change and not only never is but never can be stationary” (Schumpeter, 1942, p. 83).

Recognising objectivist (things as objects) and process (things as processes) ontologies, Van de Ven and Poole (2005) bridge the two and describe alternative increments between them. Table 4.1 (adapted from Van de Ven & Poole, 2005) summarises four alternative approaches bridging the view of all things as processes to the view of all things as objects.

Table 4.1 Four alternative approaches to ontology of Processes / Objects

Approach I	All things are processes.	All things can be explained as processes. This is the most radical process perspective. It reflects the Heraclitean perspective that the river is an ever-changing flow.
Approach II	Processes are primary, but they create objects.	Processes are primary, but objects exist. Processes engender, determine, and characterise things, but objects exist independent of processes. Phase-based models of change, such as the lifecycle approach, are a common representation of this.
Approach III	Objects are primary, but they are impacted by processes.	Objects are primary but enact processes. Objects are the focus of and are described as the centre point of analysis. This reflects Aristotle’s perspective of reality and is the common ontology of most organisational theory.
Approach IV	All things are objects.	Objects are primary. There are no processes, and all representations of process offer only surface description of objects. This reflects Plato’s perspective of reality.

The position of this research

This research adheres to the ontological position of Approach II, where processes are primary but create objects. This aligns with the suggestion of Van de Ven and Poole (2005, p. 22) that phase-based process models fit within Approach II.

4.2.2 **Epistemology – the way we know things**

The literature provides much discussion of the differences between process research and variance research (Langley, 1999; Mohr, 1978; Poole & Van de Ven, 2004; Van de Ven, 2007). These two types of research differ as modes of explanation (Mohr, 1982, p. 36). Process research investigates unfolding sequences over time, looking for patterns of change (Langley et al., 2013, p. 1), with a strong focus on narrative as a central component of description. Variance research instead investigates the relationship between variables (what effect does X have on Y) and is the more common representation of the scientific method (Mohr, 1982). The choice between these two methods represents what Van de Ven (2007) refers to as a fork in the road and requires distinctly different methods as well as related expectations. Whilst both types of research are valid, they are also methodologically distinct, where research should be designed with reference to the selection made (Van de Ven, 2007).

This research has been designed as process research and fits within the methodological expectations and criteria of this perspective.

4.2.3 **The role of models in innovation research and the generalisability of knowledge**

The presentation of theoretical models has a long history in innovation research. Godin notes that within the innovation literature, models make things visible, serving a pragmatic purpose of organising knowledge, and giving social existence to particular ideas (Godin 2017, location 151). Reviewing the long history of models within the innovation literature, Godin also notes the role of both analytical and mathematical models. This research clearly provides an analytical model rather than mathematical, and Godin notes that the purpose of analytical models is to offer a rhetorical device, a focussing lens through which to see phenomena. From this perspective, the generalisation claims of this thesis reflect the nature of the model it utilises (Eisenhardt and Graebner 2007). This thesis and the model within, are primarily a tool to describe particular characteristics of phenomena as it emerged in the case study, and for the model to bring forward the focus on particular characteristics of innovation. As discussed with references to the problems of abstraction (in section 4.1.1), the generalisability claims of this thesis are consistent with other prominent innovation case studies, limited primarily to the case in focus.

4.3 Case study overview

This research is an in-depth single case study. The rationale for the choice of case study research comes from existing innovation process research (Suurs, 2009; Van de Ven et al., 1999) as well as from Yin (2013, location 640–962), who identifies that case study research is a suitable method where the research questions are "how" or "why" questions and the researcher is motived to understand a real world case where there exist important contextual conditions.

4.3.1 **Case study overview and choice**

The case study for this research is portable digital music players (recognised colloquially as MP3 players). This study retraces the history of this technology, describing its prehistory through to maturity and using this to explore why innovation was possible at one time and not others. This particular case study was chosen for the following reasons.

1. Historical case study

With reference to the problems of prospective innovation previously discussed in this chapter, a successful innovation from the past was chosen. Historical research is a well-accepted style of research in the innovation literature (e.g., Basalla, 1988; Constant, 1980) and avoids the complications of selecting a technology developing in real time or prospectively before the story is complete, or indeed selecting a technology that may not lead to innovation.

2. Availability of data

Acknowledging the need to cover both successful and unsuccessful attempts at innovation also discussed in section 4.2, a strength of the selected case is that despite being historical, there is a large amount of high quality data. The development of digital music had a high profile internationally, resulting in a vast amount of web articles, blog posts, user forum discussions, interviews, and keynote addresses all published on the internet in real time during development. Thanks specifically to the Internet Archive (http://archive.org/web/), almost all of these websites, including published articles, blog posts, forum discussions, and recorded audio and video, have been preserved and remain intact in chronological order. This represents a powerful archive.

The combination of a high-profile case resulting in a large volume of data, along with the almost complete preservation and maintenance of this real time data by the Internet Archive, provides a vast and rich data set for analysis that avoids biases of retrospective recall and survivorship (Yin, 2013).

Supplementing this data, primary expert interviews were completed for this study. With the research primarily investigating events between 1995 and 2008, there are many expert protagonists alive and available for interview who have strong recollections from this time and provide important insights and reflections to supplement the large volume of secondary data.

3. The birth of the internet

Another reason that this case study was chosen is the impact of the internet. Digital music was one of the first and is still one of the most dramatic accounts of industry disruption caused by internet-enabled computing. Prior to digital music, the internet was new, and its value to consumers was largely unclear. The emergence of the ability to download music has been cited as the catalyst for initiating consumer adoption of broadband internet (see case study sections 8.3, 9.24) and the subsequent verve with which consumers did so resulted in dramatic change to much of the existing record industry.

Since this, computing has become a more powerful example of an epochal technology (Kuznets, 1966; see also Freeman, 1992; Gawer & Cusumano, 2002; Lipsey et al., 2005), and disruption (Christensen 1997) is now commonplace. Waves of industries have followed the music industry to becoming similarly disrupted and reorganised around digital technologies (Perez, 2009). With the capacity of computing continuing to advance and reaching unprecedented levels of performance, this trend is set to continue (Andreesen, 2011). Industries that were only distantly connected to the computing industry, much like the music industry once was, such as education (Christensen et al. 2008a) and health care (Christensen et al., 2008b), now find themselves susceptible to disruption due to digital technology, in much the same way that it occurred with music. Offering analysis of how internet-enabled innovation occurred for digital music has relevance for new industries being reconfigured around these and similar technologies.

4. An important time for the record industry, and wider relevance

A final reason for the choice of case study is the relevance of music. In his keynote address when first publicly releasing the iPod in 2001, Steve Jobs justified Apple's decision to enter the digital music market by acknowledging music's pervasive relevance: "Music's a part of everyone's life. Everyone. Music has been around forever. It will always be around. This is not a speculative market. And because it's a part of everyone's life it's a very large target market all around the world. It knows no boundaries" (Jobs, 2001). Consistent with this, music represents a universally relevant and familiar case, and one that will continue to be an important part of culture that further offers relevance in light of expected ongoing industry change.

4.3.2 **Boundary conditions**

The establishment of boundary conditions is an important task in process research (Van de Ven, 2007; Poole et al., 2000). The boundary conditions are important to give clarity to the scope of relevance to the study.

4.3.2.1 Single case study

This research is a single case study of portable digital music players and does not offer multicase comparison to other industries (Yin, 2013, location 4480). Within the innovation literature, both multicase and single case designs are common, with both accepted research designs (Dewald & Truffer, 2011; Jacobsson, 2011; Suurs, 2009).

4.3.2.2 Date boundaries

The date boundaries of this case study are broad. To establish the role of context and accumulation that preceded the emergence of portable digital music players, the initiation boundary of this study is particularly early. The case study acknowledges events in history as far back as, briefly, the 11^{th} century. More consistent data events are identified from the 1950s to the 1990s, utilising the emergence of music industry trade journals. Precedent technologies such as transistor radios, Walkmans, and portable CD players are all acknowledged in the narrative. The narrative also traces similar developments in the computing industry related to computer music from the 1950s on, including the emergence of mainframe computers, microcomputers, and personal computers.

The majority of data for this study comes from the emergence of the first portable music players prototypes in 1994 to the end boundary of this study, which is 31 December 2007. This end date was chosen because whilst the iPod (classic) continued to be sold until 9 September 2014, it slowly receded in sales from 2008 on. The end of 2007 was chosen to end the study because in June 2007 Apple released the iPhone, which was seen as a “convergence device”. Further research opportunities exist to describe the development that occurred to the technology from 2008 on, but this is outside the scope of this study.

4.3.2.3 Retrospective case study

This study is a retrospective case study. Data collection and analysis did not occur in real time. This study began in 2010, after events had already occurred. As Poole et al. (2000) note, retrospective analysis has a range of benefits and risks. The benefits are that due to the completeness of the process, the narrative has the benefit of hindsight, which lends perspective to analysis. It also takes less time to collect data, allowing for an expanded date range to be offered in the narrative. Much like Knudson and Ruttan's (1989) research, this research has resulted in a vast narrative that spans events over a number of decades.

The risks of a retrospective case study relate primarily to awareness of outcomes. Whilst all actors and events unfold in real time under conditions of uncertainty, the construction of a retrospective narrative can lead to bias as the researcher can distort or omit data that doesn't reflect the uncertainty of the process (Poole et al., 2000, location 1590), resulting in a narrative that appears deterministic. This has been countered in this study by tracking the broadest possible generic search terms of "digital" in music industry data, and "music" in computer industry data to capture and describe uncertainty and development as it occurs. Rather than starting with more specific terms such as "MP3" or "Napster", tracing generic terminology highlighted precedent technology and a variety of explored avenues, including failed ones, as well as momentum shifts in the nature of experimentation and expected success over time. The event history narrative is over 500 pages long, with a strong focus on the detail of this experimentation rather than only outcomes of success. Another known disadvantage of retrospective case studies is that this method has limited data flexibility, as "researchers must make do with what has been preserved" (Poole et al., 2000, location 1870). As mentioned above – and as will be further explained in the data section –This case study was chosen because of the vast amount of data that is available via both the internet archive, as well as through primary interviewees.

4.3.2.4 Boundaries of focus

To describe the cumulative causation that preceded the emergence of the first portable digital music player, this research traces the history of emergence and awareness of digital music technologies in both the computer and the music industries. In practice, as developments were connected it was difficult to instigate boundaries, and, as a consequence, it was decided for thoroughness to go back to the start of both industries and retrace digital from its inception. This meant a great deal more work, but it has produced a more complete narrative. It has a focus on tracing the history of "digital" technologies in the music industry, as well tracing the history of "music" applications in the computer industry. This also incorporates related developments referenced in both industry source data that includes the consumer electronics industry, as well as the more general radio and electronics industries. Retracing these separate histories provides a strong foundation for a description of how and when these industries began to intersect, leading to the emergence of portable digital music players.

4.4 Data Overview

This case study utilises three main sources of data: secondary documentation, archival data, and in-depth primary interviews. Whilst there are many alternative types of data and directives regarding collection (see, for example, Berg & Lune, 2004; Bouchard, 1976; Merriam, 1998; Patton, 2005), as this is specific case study research, it will use the guidance of Yin (2014), who provides a discussion of data specifically from a case study perspective. This is also supplemented with directives offered within the process research literature (Poole et al., 2000; Van de Ven, 2007; Langley, 1999). An overview of the data will now be provided.

4.4.1 **Secondary Data**

4.4.1.1 Documentation

This research employs extensive secondary documentation data. As part of this study a large volume of articles were collected and analysed (more than 4,000 individual articles). This data is vast enough to describe the prehistory through to maturity of portable digital music player technologies. Over this progression, a number of alternative data sources emerged at different times, and trade publications of both the music and computer industries are utilised, as well as specific digital music sources as these sources emerged. The digital archives of these publications are searchable by key term. For music industry publications, the search term used was “digital”. For the computer industry, the search term used was “music”. This gave a large amount of references that were then read and coded. As digital music technologies emerged, so too did a range of digital music technology-specific websites, which provide a large number of articles that document the issues of development that occurred for digital music player technologies. The use of four separate website archives provides a large amount of data (over 2,000 articles) to document the process of development. Each of these sources will be discussed individually below, beginning with digital music technology-specific websites.

4.4.1.1.1 Digital music technology-specific news websites

As digital music technology emerged, it brought with it a range of websites that documented the development of the technology in real time. These websites, which started in the late 1990s, now represent a large archive of articles that document the development of digital music in real time between 1998 and 2008. Four specific websites – MP3 Rocks the Web, MP3 Newswire, Music on the Internet, and MiniDisc.org. – offer over 2,000 published articles on digital music technologies. A summary is provided in the table below.

Table 4.2 Specific news website sources

Publication Title	**Publisher**	**Summary**	**Date range**
MP3 Rocks the Web	Wired.com	An Wired.com website dedicated to publishing MP3-related news.	Established: 1999 Last entry: 2005
MP3 Newswire	Richard Menta	An independent website aggregator of MP3-related news.	Established: 1998 Last entry: ongoing
Music on the Internet	*New York Times*	A *Times* website dedicated to publishing MP3-related news.	Established: 1999 Last entry: 2001
MiniDisc.org	Sumit Shah and Eric Woudenberg	An independent website dedicated to minidisc related news.	Established: 1998 Last entry: ongoing

4.4.1.1.2 Computer industry–specific publications

Prior to the emergence of digital music technology-specific publications, a number of computer industry publications were accessed and searched. These magazines capture development that occurred from the 1970s through to the 1990s. They were accessed through either the Factiva database or via the large volume of computer industry magazines that have been digitised by the Internet Archive. (See the table below for a summary of these sources.)

Table 4.3 Computer industry publications sources

Publication Title	Publisher	Summary	Date range	Accessed via:
Byte Magazine	UBM	Leading micro- and home computing magazine through the 1970s and 1980s.	Sep 1975–July 1998	https://archive.org/details/computermagazines
PC Magazine	Ziff Davis	A leading personal computer magazine, focusing on product reviews, upcoming releases, and computer commentary.	Jan 1982–	Factiva
MacWorld Magazine	Mac Publishing IDG	A leading Apple Macintosh computer magazine, similar to that of *PC Magazine* but with an almost exclusive Apple focus.	1984–2014	Factiva
Computer magazine archive	Various	Search results from computer magazine archives for "music".	Various	https://archive.org/details/computermagazines

4.4.1.1.3 Record industry–specific publications

Record industry publications were also searched for references to digital music. Because of its recognition as the longest standing industry magazine, *Billboard* was selected as the primary source and a detailed search and study of *Billboard* was produced, with over 700 articles included for the search terms. (See table below for a summary of these sources.)

Table 4.4 Record industry-specific publication sources

Publication Title	Publisher	Summary	Date range	Number of articles used in this study
Billboard Magazine	Billboard Inc.	Leading record industry trade magazine.	Pre-1877 – ongoing	700 individual articles

4.4.1.1.4 Radio-specific publications

To supplement the use of *Billboard*, a number of radio technology trade and hobby magazines were utilised. This captures audio technology development from the 1920s onwards. See the following table for a summary of these sources.)

Table 4.5 Radio-specific publication sources

Publication Title	Publisher	Summary	Date range
Radio Craft/Radio Electronics/Popular Electronics	Hugo Gernsback	A leading magazine on the radio and electronics.	1929–2003
Radio Attic Archive	Steven Adams	An online archive dedicated to radio technology http://www.radioatticarchives.com/	Extensive
Smithsonian history of headphones/ Various	Smithsonian Musician	A history of headphone technology, which provided references for further research from other locations	Single publication

4.4.1.1.5 Science fiction-specific publications

Investigating the recognition of music in science fiction, a range of science fiction databases were utilized. These offer history related to the prediction of music/portable music in science fiction. (See the table below for a summary of these sources.)

Table 4.6 Science fiction-specific publication sources

Publication Title	**Publisher**	**Summary**
Technovelgy.com	Bill Christensen	A website dedicated to technology references in science fiction.
http://www.sf-encyclopedia.com/entry/sf_music	Open source	A user generated encyclopaedia of references in science fiction about music.

4.4.1.2 Secondary interviews

Due to the high-profile nature of digital music, there are a number of recorded individual interviews and panel discussions that are available online with key protagonists. Some were recorded during particular developments, while others are more recent retrospective interviews that recall and reflect on events. (See table below for a summary of these sources.)

Table 4.7 Secondary interview sources

Publication Title	**Publisher**	**Summary**	**Date**	**Length of interview**	**Original source**
Kane Kramer	*The Guardian*	Interview with Kane Kramer, creator of the IXI digital music player.	6/5/09	24min 26s	http://www.theguardian.com/technology/blog/audio/2009/may/05/tech-weekly-kramer-audio-mp3-player
Michael Robertson	*This Week in Startups* [online video interview]	Interview with Michael Robertson, founder of mp3.com.	20/2/2010	2hr 34min 14s	https://www.youtube.com/watch?v=S5pzwCh2IeU

Publication Title	Publisher	Summary	Date	Length of interview	Original source
Jeff Patterson	CNN	Interview with Jeff, co-founder of Internet Underground Music Archive	3/9/1994	2min 37s	http://youtu.be/GT5LIEUJefM?list=PLecSxqIJa9I_291M2ZynCENcSmHDYVUae
Steve Jobs	International Design Conference Aspen	Steve Jobs discusses the future of computing, in a talk titled “The Future Isn’t What It Used to Be”	1983	54min 21s	https://www.youtube.com/watch?v=Nyp52pt1EvY

4.4.1.3 Product launch material

A range of recorded Apple keynote addresses are available that relate to relevant portable digital music player product launches and company strategy. (See table below for a summary of these sources.)

Type	Date	Summary	Location
Apple keynote: Steve Jobs	Jan 2001	Macworld 2001: iTunes, digital hub strategy, and PowerBook G4 introduction	https://www.youtube.com/watch?v=9046oXrm7f8 https://www.youtube.com/watch?v=auXc0tgdJSo
Apple keynote: Steve Jobs	Jan 2001	Macworld 2001 (same presentation as above): The release of iTunes	https://www.youtube.com/watch?v=IF_c5KSK0-A

Type	Date	Summary	Location
Apple keynote: Steve Jobs	23 Oct 2001	Apple special event: The release of the iPod	http://everystevejobsvideo.com/original-ipod-introduction-apple-special-event-2001/
Apple keynote: Steve Jobs	2002-2008	Yearly or half yearly keynote addresses, with product releases of various iPod products	Various

4.4.1.4 Archival Data

In addition, a range of archival data is available and has been utilised. (See the table below for a summary of these sources.)

Table 4.8 Archival data sources

Publication Type	Source	Summary
WebNoize internal documents	Unpublished: Joanne Marino	Summary of WebNoize attendee list, programs, and attendee analysis provided by Joanne Marino.
Product website pages	Internet active	Various web pages for individual products.
Apple Inc.	Apple Inc. financial statements	Breakdown of iPod sales per year, Oct 2001–Dec 2012; all information sourced from Apple Inc. financial statements (links provided in spreadsheet).
Microsoft internal emails	Made publicly available during court case	A number of internal emails between management of Microsoft which discuss the iPod were made public as evidence in Combes v. Microsoft.

4.4.1.5 Consumer forums

There are a number of archived consumer forums that provide insight into consumer perspectives, particularly at the launch of the iPod. These represent an archive sample of consumer sentiment at the time of the iPod launch. (See table below for a summary of these sources.)

Table 4.9 Consumer forum material and sources

User Forum	Slashdot.org	A user forum with entries made by consumers who discuss their reaction to the iPod soon after its release.
User Forum	Macrumours.com	A user forum covering both the release of the iPod and the early weeks following.

Table 4.10 Consumer forum material and sources

This summarises the secondary data utilised in this study. All data is stored in an Evernote account.

4.4.2 **Primary data**

To supplement the secondary data above, and to increase the validity of the research by using a diverse range of data (Yin, 2013), a series of one-on-one semi-structured interviews were conducted specifically for this study. One-on-one interviews were deemed appropriate as they offer means to gain insight and understanding (Gillham, 2000) above that of the secondary data alone. Purposive expert sampling was employed (Miles, Huberman & Saldana, 1994) for the selection of participants. The selection criteria employed required respondents to be directly acknowledged within the secondary data (articles) as experts or primary protagonists in the development of digital music.

4.4.2.1 Completed expert interviews

Fifty-two experts were approached via email, and of these 17 agreed to and completed interviews. This represents a 30.7% acceptance rate, with the total of 16 completed interviews also within the range suggested by Polkinghorne (1989), who identifies that between five and 25 individuals with experience in a phenomenon under investigation is a suitable basis for interview data collection. The combination of both the achievement of this benchmark as well as the use of interviews as a secondary data source strengthens the reliability of this study. A complete list of approached experts including declines and nonresponses is provided in the case study protocol. The list of completed interviewees is provided in the table below. These experts offer a direct account of the development of digital music, offer unique perspective on this development as its protagonists, and offer informed insight and opinion with respect to key developments.

Table 4.11 Completed primary expert interviews

Expert	**Position/Expertise**
Professor Karl Brandenburg	Creator of the MP3 file format, member of Secure Digital Media Initiative.
Hank Barry	CEO, Napster (peer-to-peer music trading software).
John Chowning	Creator of digital frequency modulation (FM) synthesis.
Thomas Dolby	Grammy Award-winning synthesiser artist, founder of multiple multimedia companies.
Julie Gordon	Copywriter for Apple's iMac and iPod campaigns, creator of "Rip. Mix. Burn." headline
Ken Hertz	Artist lawyer representing clients such as Alanis Morissette during this time. Member and attendee of the Secure Digital Music Initiation.
Andy Hill	IBM employee, followed by founder of Multimedia Archive and Retrieval System (MARS)
Jeff Levy	University student prosecuted for copyright infringement due to online file sharing by the U.S. government.
Joanne and Tom Marino	Co-founders of online digital music news website www.webnoize.com, along with related yearly Webnoize conference.
Phil Morle	CTO, Kazaa (peer-to-peer music trading software).
Jeff Patterson	Co-founder of the Internet Underground Music Archive (IUMA), recognised as one of the first websites to download music on the internet and top 10 website worldwide for traffic during the mid-1990s.
Jon Potter	Founder of Digital Music Alliance (DiMA), a Washington-based political advocacy and lobbyist group for digital media entrepreneurs.

Expert	Position/Expertise
Kelli Richards	A&R at various major labels, PatroNet co-founder (the music distribution and fan interaction software created by high-profile Todd Rundgren in the early 1990s).
Jon Rubinstein	Vice president of engineering at Apple Computer. Recognised as critical to the creation of Apple products between 1997 and 2006 including the iMac, the iPod, and the iPhone. Leader of the initial iPod project, then subsequently head of iPod at Apple when it was established as a separate division in 2004. Left Apple in 2006, became CEO of Palm in 2008 until it was purchased by HP in 2010. Current board member of Amazon.com, Qualcomm, and co-CEO of Bridgewater, the largest hedge fund in the world.
Cary Sherman	Current chairman and CEO of the Recording Industry Association of America (RIAA), previously President of RIAA 2001–2011
Zak Zalon	President Radio Free Virgin, Virgin Digital.

Nine interviews took place in the U.S. between August and September 2013. For face-to-face interviews, I went to the location of the expert (Washington, San Francisco, Los Angeles, and New York) and conducted the interview in a one-on-one, face-to-face setting (apart from the Kelli Richards interview, which also included Hank Barry for the first 10 minutes, and Tom and Joanne Marino, who were interviewed together). The choice of location was suggested by the respondent, ensuring the data collection environment was as comfortable as possible for the respondent (Yin, 2013, location 2488). The remaining interviews were conducted over Skype (Professor Karl Brandenburg, Ken Hertz, Jeff Levy, Zack Zallon, Thomas Dolby, John Chowning, Andy Hill, and Julie Gordon).

Interviews were semi-structured, and questions were open-ended and unique to each respondent. A list of guiding questions was created beforehand, but often these were not used sequentially during the interview. The questions would be asked from memory and in the sequence of conversation, and at the end of each interview, I would consult the original list to ensure completeness (Bryman, 2004).

4.4.2.2 Transcription

The interview data was transcribed by two parties. The researcher transcribed interviews directly, and a professional transcriber cross-checked and time-stamped these transcriptions.

4.5 Data analysis

As this research is process research, the primary method of analysis is the creation of a qualitative event history analysis. This method is an explanation building method (Yin, 2013, location 3760), which results in the development of a narrative. This narrative emerges through coding of data into key events and into a final temporal narrative that describes development.

4.5.1 **Event history analysis**

Event history analysis offers a method for constructing a narrative that explains the unfolding of the temporal sequence of events. The method is common in process research (Van de Ven et al., 1999) and is also employed occasionally in technological innovation systems research (Suurs, 2009). The narrative is built through a process of "meaningful parsing" (Pool et al., 2000, location 1794) of data. Through the identification and coding of "events", a narrative emerges and is refined. Events are not necessarily individual raw data points (although they can be) but are seen as important thematic changes or developments in the narrative (Poole et al., 2000, location 1752).

4.5.1.1 Development of narrative

Data was preliminary coded chronologically with events identified in sequence beginning with the earliest data first through to the end boundary of 31 December 2007 last. The narrative data is not evenly distributed through this range, but instead the profile of the data reflects the emergence of the technology, with the majority of data occurring between 1994 and 2007. In this way, the narrative does not reflect a uniform time sequence; instead, the narrative is event-driven.

4.5.1.1.1 Key assumptions of process research narrative production

There are guidelines regarding a number of key assumptions of narrative that are explored in the process methodological literature (Poole et al., 2000, location 560–679). These are identified and described for the case study in the table below.

Table 4.12 Key assumptions of this process research, Poole, Van de Ven, Dooley, & Holmes, 2000, location 560-679

Process theory assumption	**Description**	**Example**	**This study**
Unit of analysis.	The unit of analysis is an evolving central subject that makes events happen and to which events occur. While attributes of a central subject may change, the entity itself may also change through a number of processes.	*y* may change its attributes as a result of particular events in its development. At the end of the studied time, *y* has merged with *x* to create *z*, and *y* is qualitatively different to itself at the start.	Portable digital music player is the unit of analysis, and the central subject of the narrative. However, to capture the prehistory of this technology, the narrative offers detailed coverage of preceding events more generally related to digital music.
Explanation is based on necessary causality.	Processes are accumulative and exhibit path dependent characteristics. However, human agency and decisions are the cause of process and path. As such, events are probabilistic rather than deterministic.	The precursor x is a necessary condition for the outcome y, but it cannot be said ‘precursor results in outcome y.	Developments in portable digital music technology are acknowledged to emerge in uncertainty, and are nondeterministic, with many alternative paths possible.

Process theory assumption	**Description**	**Example**	**This study**
Final and formal causality, supplemented by efficient causality, is the basis for explanation.	Narrative explanation employs efficient causality to explain the influence imparted by particular events and often, to explain the mechanics of transitions between events and between microlevel units, such as phases (location 549). Final causality posits an end or goal that guides the unfolding of development and change.	The final goal of y is __, and it was achieved through development which included events a, b, c.	Final and formal causality for the narrative is the widespread diffusion of portable digital music players. This is used as the basis for the end date of 31 December 2007.
The generality of explanations depends on their versatility.	Similar to variance theories, process theories are evaluated on the basis of their generality. However, the generality of a narrative explanation stems not from its uniformity and consistency but from its *versatility*, the degree to which it can encompass a broad domain of developmental patterns without modification of its essential character.	The narrative of y is similar to that of z, or the narrative of y is not appropriate to represent that of z.	The narrative is used in the application of the technological lifeworld model, with the versatility of the narrative explored in the discussion chapter.

Process theory assumption	Description	Example	This study
The temporal sequence of independent variables is critical.	The order in which causal forces come to bear is crucial in narrative accounts. The order in which events occur in narrative determines when efficient causes come into play, while the duration of envoys and the continuity across events determines how long these causes operate. Stagewise models of development posit that differences in order can make large differences in outcomes (location 655).	x began with this event, which lead to this direction and effect. Without x the direction would be different. y began with this event, which lead to this direction and effect. Without y the direction would be different.	This is a critical characteristic of the narrative. Events related to portable digital music players were investigated and described in chronological order, recognising the momentum and impact of events as they emerged, rather than focusing on end states for efficiency.
Explanations should incorporate layers of explanation ranging from immediate to distal.	If variance theories are “causally shallow”, process theories are “causally deep”. They explain the state of development at any point in time in terms of the prior historical events and associated causal influences. In process theories, history cannot be encapsulated in the immediate past state of the entity, because the ordering and context of previous events is critical to narrative explanation (location 667).	The presence of event f was short but had an extended influence in the narrative of development for y.	Coding of event occurred chronology but not with equal time intervals. Intervals were defined by significance to the narrative.

Process theory assumption	**Description**	**Example**	**This study**
An entity, attribute, or event may change in meaning over time.	The process approach presumes that the unit of analysis may undergo metamorphosis over time. So the entity may be fundamentally transformed into a different type of unit, merge with another unit, or go out of existence over the course of the narrative.	Event f proved critical in y's narrative, halting all development or causing y to merge with z.	The co-development and combination of components in related fields of personal computing, the internet, and the consumer electronics industries are all critical characteristics of the narrative.

4.5.1.2 Narrative construction process

The narrative was constructed by three pass construction. Each will each be described below.

4.5.1.2.1 First pass

The first pass occurred in the data collection stage, with identification of relevant large archives of data (such as the complete archive of *Billboard Magazine*, *PC Magazine*, etc.). For each large archive, a search term was selected that was both sufficiently broad as well as appropriate for the nature of the publication. The diversity of the data chosen (from alternative industries that proved relevant to digital music) required a number of individual search terms. Table 4.13 below presents a summary of the first pass terms used.

Table 4.13 First pass narrative exploration terms

Source	**Search term**
Billboard Magazine	Digital
Computer archives	Music
Radio magazines	Portable/portable music
Science fiction references	Music/Portable music/Portable entertainment

The search results returned a large volume of articles through a large time scale. Each article was individually read and assessed for inclusion in the Evernote database. The first pass provided a large volume of relevant articles included in Evernote. Due to the general search terms, and the large volume of articles returned, the narrative was not yet formed, and key events were not yet clear, but this data provided the basis for further exploration. This collection method took 12 months.

4.5.1.2.2 Second pass

Once all data was in Evernote, the search for key events was applied as a second pass of data. This had a focus on the emergence of themes, terms, protagonists, concepts, identification of stakeholders within data, and identification of data that provided summaries and forecasts. This too was done in chronological order, with events identified in sequence beginning with the earliest data first through to the end boundary of 31 December 2007 last.

This second pass was an inductive method. That is, detailed analysis of all data was undertaken and coding categories were identified from the ground up. As both Yin (2013) and Poole et al. (2000, location 1952) identify, this method is one of two legitimate alternatives. The other is to code deductively, specifically from the perspective of preceding theory, looking for events that are relevant to the propositions. Both methods are seen as valid. The inductive method was applied largely due to the exploratory nature of the study.

Again, as stated, the unit of analysis was the technology itself, rather than any particular individual. Poole et al. (2000) make the distinction between uni-focal and multifocal coding and suggest that the researcher must make a choice between the two. As the name suggests, unifocal coding is the focus on one key concept; multifocal coding is the development of multiple concepts. Due to the complexity of the technology, as well as the number of independent actors, unifocal coding was not appropriate, and multifocal coding was employed; in this second pass, a large volume of tags emerged for data.

At the same time, primary expert interviews were being conducted. For the most part, expert respondents were not prompted on particular issues, but occasionally these interviews explored emerging themes from the secondary data.

As the narrative reached stages where the technology had been created, the technology itself, as well as the protagonists, began to have a higher profile, with a large amount of press coverage and analysis. MP3newswire and Music Rocks the Web became news websites that chronicled development, releasing a high volume of articles almost daily. As these sources emerged, the search for wider documentation became less significant, and narrative construction shifted to an exploration of key themes from these sources, exploring differences and similarities in reporting of these key sources.

4.5.1.2.3 Third pass

The third pass was the construction of the final event history narrative. This is the second volume. With the nature and order events clear, and the availability of expert primary insight, the task became writing about events in the narrative. Due to the expansiveness of the narrative, as well as the amount of detail, this was a laborious process that took 18 months. This final narrative is approximately 176,000 words (with references).

4.5.1.2.4 Fourth pass

The final stage was to apply the lifeworld model to the complete narrative, with the lifeworld model providing a lens through which to view the narrative. Similar to the method employed by Suurs (2009), the fourth pass mapped the event narrative derived in the third pass against the presented lifeworld model of the previous chapter.

Poole et al. (2000) citing Nutt (1984) in identifying that the application of the phase model is appropriate at this stage of analysis, after the creation of the narrative: "Narrative descriptions, such as Nutt's translation of case study stories into phases, are already compound representations of complex combinations of activities and typically require no further parsing" (Poole et al., 2000, location 3208).

This fourth pass is the analysis chapter. It presents the process of innovation of portable digital music players using the lifeworld model.

4.5.1.3 Reliability of coding method

There are risks of reliability associated with the creation of narrative. Citing from Bakeman and Gottman (1986, p. 3), Poole et al. (2000) identify that "narrative reports depend mightily on the individual human doing them, and judgments about the worth of the reports are inextricably bound up with judgments about the personal qualities of their author". This risk is acknowledged, and it has been mitigated using real time data and multiple source data. The majority of the data in this study is real time archival data accessed via web sources. This eliminates the biases of hindsight. Also, this data has been triangulated with primary expert interviews. These interviews offer further depth and insight into issues.

Research texts offer alternative ways to ensure reliability (Yin, 2013). Particularly, these methods include having an independent coder review the data and having an expert review the narrative. In light of the triangulation strategies employed, as well as the expansive detail, an independent coder was not used.

4.5.2 **Ethics and participant review**

Ethics approval for this research was granted on 13 June 2013 and expires 30 June 2020. Ethics approval was granted before the commencement of in-depth expert interviews.

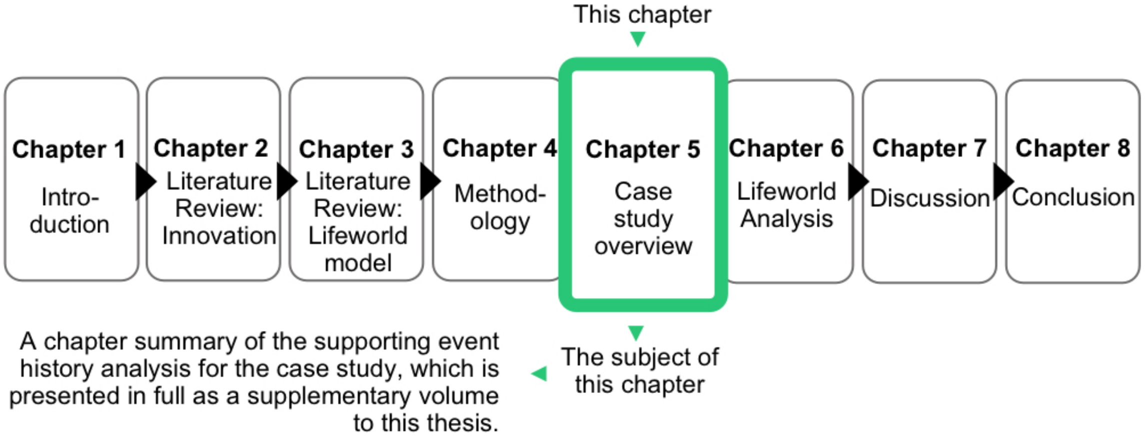
Please note, there are also some sensitivities as a result of the public profile of many of the experts interviewed for this study. The expert respondents currently or have previously represented large scale industry bodies with constituents, public traded companies, research institutes, or more generally have a profile related to their expertise. Agreeing to be identified in this research at the time of the interview brings participants risks to their profile, institutions and positions based on what the outcomes of the research are. As a consequence, each expert will be offered capacity to review this research prior to publishing. Each participant has been given the opportunity to review the study with the right to withdraw from the study at any time with no consequence. Whilst it is not anticipated that any expert will choose this outcome, for ethical transparency this may occur, and if so there will be some revision to the expert list of interviewees as well as related sections of the study. To further offer assurance to these experts, an embargo period for this research of 18 months post-submission will occur.

4.6 Chapter Summary

This chapter provided an outline of the research method for this study. It identified the process methodology of this research and provided an overview of the data, the collection methods, and the analysis methods employed. The next chapter presents the narrative.

Chapter 5

Case Study Overview



5.0 Introduction

This chapter presents a summary of the case study presented as the second volume. Each event discussed in this analysis chapter has a corresponding section in the case study, with the case study providing a significant amount of further detail.

Events in the case study and this analysis chapter are presented chronologically and cover events related to portable digital music players from prior to 1877 through to the end of 2007. This is an extensive timeframe, in part to cover much of the precedent history of portable digital music players. The majority of events though, emerge with the majority of activity, which occurred between the years 1994 and 2008.

5.1 Before 1877

Music is described as a deep habit of humanity, a universal language traceable back to the earliest of historical cultures (Byrne, 2012). From the 11th through to the 19th centuries, music became codified, and with this "classical" music emerged iconic composers such as Wagner, Beethoven, Mozart, and Bach. This music was created prior to recording technology being available; it was exclusively a live experience.

At the same time, there were imaginative descriptions of recorded music in science fiction (see Table 5.1).

Table 5.1 Science fiction descriptions of recorded music

Date	Event	Description	Case study section
1626	Science fiction	Francis Bacon describes the concept of sound houses in New Atlantis.	2.0
1888	Science fiction	Bellamy describes recorded music as a characteristic of a future utopia.	2.0

5.2 1877–1949

Edison's 1877 "talking machine" and Emile Berliner's gramophone, patented in 1887, eventually led to the recorded music industry, but it took time to advance the designs beyond raw technology and even to find the application of music. The first 10 to 20 years after the invention saw much experimentation with the technology: first, cylinders were used to record sound, then shellac, and then, finally, vinyl, which offered superior durability. The use of the technology for recorded music was not obvious at first. Edison initially identified the gramophone as a tool not for music but as a supplement to the telephone; to him, it was principally a tool to record speeches, conversations, and sermons. Musicians who attempted to record through the early technology viewed it as a poor parody of live performance.

But, with time, music began to emerge as a powerful use of the gramophone, with both Edison and Berliner being responsible for two of the largest record labels of the time. The first recording artist was Italian tenor Enrico Caruso, who signed to Victor in 1902. By 1949, RCA, Victor, Columbia, Decca, and Capitol had become major labels, built around pop, classical, and early jazz (Heffernon, Lebowitz, & Stratton 1984, p. 9). By this stage, too, a range of smaller, niche “independent” labels had been created, such as Atlantic, Elektra, and Blue Note (Heffernon, Lebowitz, & Stratton 1984, p. 9).

Early record labels sold records as well as the record players themselves, but an independent industry of gramophone manufacturers soon developed. Portable gramophone players, too, quickly became a niche focus for some manufacturers.

The record industry was soon aided by the creation of broadcast radio, which drew from the ship-to-ship Morse code technology of Marconi (Levinthal, 1998). This spurred the growth of the recording industry to the extent that by 1949, revenues had reached $183 million annually.

Whilst not yet popular, magnetic reel-to-reel tape (1935) and headphone technology were also created in this time, as was the first electrified amplification method (see Table 5.2).

Table 5.2 The initialisation of the record industry

Date	**Event**	**Description**	**Case study section**
1877	Creation of gramophone/phonograph	In the same year, Berliner and Edison independently create similar recording technologies.	3.1
1904	Recording industry	First recording artist signed in 1902.	3.2
1935	Magnetic tape	First magnetic tape created, demonstrated in the Magnetophone.	3.5
1949	Recording industry	The recording industry reaches revenues of $183 million.	3.2

Entering the 1950s, both radio technology as well as recorded music technology continued to strengthen, and recorded music grew in size dramatically in this period (for example, record sales revenues increased from $213 million in 1954 to $603 million in 1959) (Garofalo, 1999, p. 336). The vinyl record was a strong technology of the record industry in this period. There were significant developments that soon added to this. The emergence of transistor radios and cassette tapes further developed the industry (see Table 5.3).

Table 5.3 Growth in the recording industry

Date	Event	Description	Case study section
1954	Creation of the transistor radio.	Based on technologies from Bell Labs, the transistor radio precipitates the entrance of a range of new companies into the market and becomes a popular consumer device.	4.1
1957	Stereo recording.	EMI releases the first ever stereo recording.	4.2
1950–1960	Record industry.	The recording industry continues to grow: The RIAA is formed in 1953, and in 1960 the first Tower Records opens.	4.4
1963	Cassette tape.	Phillips introduces the cassette tape, initially thought of as a tool for business dictation.	4.3
1979	Bone Fone.	Attempts to create a portable transistor radio continue, notably with the Bone Fone, a radio in a sleeve that sits around the neck.	4.1

The creation of the transistor at Bell Labs soon led to new applications being found elsewhere, such as at Shockley Semiconductor (where Gordon Moore worked), and IBM, which began to offer mainframe computers that would be used by NASA and the airline industry (see Table 5.4).

Table 5.4 Initialisation of computing

Date	Event	Description	Case study section
1946	Creation of ENIAC.	The U.S. government funds research to design the first digital computer, a calculating machine of artillery firing tables for the U.S. Army.	4.5

1952	IBM	IBM, then the largest producers of punch-card technologies, shifts to manufacturing electronic digital computers.	4.5
1962	IBM 9090	IBM creates the 9090 mainframe computer, which is used by NASA and is the basis for American Airlines's SABRE reservation system, which by 1968 handles 100,000 flight reservations a day. The computer earns IBM $30 million.	4.6
1965	Moore's law	Gordon Moore publishes his thesis, which describes the transistor counts of computers doubling every 18 months – a thesis that holds true for over 30 years. Others, like Ted Nelson, also recognise the decreasing price and increasing performance of computers at the time.	4.6
1974	Minicomputers	Digital Equipment Corp dominates the microcomputer category. Their first 8-bit model, released in 1957, had 4 KB of memory and cost $18,000. By 1974, DEC has sales close to $1 billion annually.	4.6
1977	Altair	The TV typewriter concept initiates the concept of home computing and leads to the Altair home computer kit. The Altair becomes a landmark product that launches the home computer category as well as the now-famed Homebrew Computer Club, a group of computer enthusiasts that includes the founders of Microsoft, Apple, Commodore, Oracle, and IBM. Other computers soon follow, such as the IMSAI 8080, Radio Shack's TRS-80, and the Apple I and Apple II.	4.7

During this time, there were a number of developments in computers specifically in the field of music. These will be discussed below (see Table 5.5).

Table 5.5 Digital computers and music

Date	Event	Description	Case study section
1951	Kathleen MacLean's "Incommunicado"	MacLean publishes a story in *Amazing Science Fiction* about computers being used for music.	4.8
1957	Max Mathews at Bell Labs creates the first digital music using a computer.	Mathews writes Music I software for the IBM 704 and uses it to create the first digital piece of music, called "In the Silver Scale", an arpeggio piece lasting 17 s. In 1961, Mathews updates the software, using an IBM 7094, and creates a digital cover of "Daisy Bell". Mathews works with others at Bell Labs, including Laurie Spiegel.	4.8
1967	John Chowning creates FM synthesis.	John Chowning, a Ph.D. student at Stanford with an interest in music percussion, visits and works with Mathews and others at Bell Labs. He subsequently returns to Stanford to create FM synthesis, a new algorithm that uses digital computers to create complex music timbres. For the first time, computers can be used for sophisticated sound. Yamaha subsequently licenses FM synthesis and uses it in their DX7 synthesiser, which becomes the greatest selling synthesizer of all time.	4.9
1967	Pulse-code modulation (PCM)	A new digital recording method, created by researchers in Japan, creates the possibility of recording to a digital format. It is viewed as vastly superior in quality to previous analog methods like magnetic tape. By 1969, both Sony and Nippon have released PCM recorders to the market, aimed at professional studios.	4.9
1971	Digital analog converters, and growing industry	With the availability of PCM recorders, digital recording becomes a new potential direction for the industry. Articles in *Billboard* in 1971 discuss analog-to-digital	4.9

	recognition of digital.	converters for the first time. In 1974, digital music recording is discussed at a panel discussion at the Consumer Electronics Show.	

5.3 1979–1984

The Sony Walkman was released in 1979 and quickly became a consumer phenomenon, bringing portable music to life. Within 10 years, 50 million Walkmans were sold; by 1995, that number had increased to 150 million, and the Walkman had become a cultural icon. Created using relatively simple technology, the Walkman brought together Sony's experience in other products, such as business dictation cassette recorders and its new prototype headphones (created independently by another division at Sony). Sony founder Akio Morita brought them together to create the Walkman, the success of which made Sony a dominant global brand.

As a consequence of the Walkman, the cassette became a second parallel technology of the recording industry, which continued to grow in revenues. Blank cassettes revealed the deeper problem of piracy, as home taping became a focus of discussion for those in the industry.

Digital recording also became a focus for the major labels. Continuing on from earlier developments with PCM recording and analog-to-digital converters, there emerged a competition between the major labels as they began to embrace digital. Viewed as superior in quality to analog, digital audio became a popular topic for the industry, with progressive investments in the technology made by the major labels. Table 5.7 below highlights some of these major achievements.

Table 5.6 The birth of the Walkman, continued growth of the Recording Industry

Date	**Event**	**Description**	**Case study section**
1979	Sony releases the Walkman	Akio Morita and the team at Sony bring together a number of existing technologies to create the Walkman, which invents a new category of consumer electronics and becomes a consumer phenomenon.	5.1
1979	CBS Records stores recordings in digital format	CBS Records uses digital PCM recorders to store Ornette Coleman's *Of Human Feelings* LP on "software cassette". All	5.3

		major labels invest in and pursue digital recording technology.	
1981	Vinyl record sales	In 1981, 1.14 billion vinyl record units are sold, an all-time high for vinyl unit sales. From 1982 onwards, vinyl sales retract as cassette sales emerge.	5.2
1982	Home taping	Cassette sales reveal the rising threat of piracy as home taping becomes a recognised issue.	5.2
1981/1982	Major labels	The major labels explore the concept of a home music store, where music is offered via cable service. With pressure from music retailers, the trial does not progress.	5.5
1979-1983	Kane Kramer	British entrepreneur Kane Kramer creates drawings for a prototype portable digital music player. The device looks similar to players that emerge much later. Kramer, however, fails and is unable to create the device.	5.5

At the same time as these developments in the record industry, the personal computer became a more fully fledged product category (see Table 5.7 below), with a range of landmark releases from a range of companies, such as Commodore, IBM, and Apple. The growth in the PC category was due to a new range of hardware products as well as clearer utility. The PC became a business tool, with applications like word processing and spreadsheets proving popular. But it didn't yet have relevance or ability as a media tool.

Table 5.7 Establishment of the PC category

Date	**Event**	**Description**	**Case study section**
1981	Growth in the PC category.	The PC begins to become a substantial category. Apple revenues for 1981 are $350 million, up 200% from the previous year.	5.4

1981	IBM 5150	Utilising a range of common parts, IBM releases the IBM 5150 PC. It quickly dominates the market.	5.4
1983	*Time* magazine declares the PC machine of the year.	Recognition of the significance of PC continues to grow. *Time* magazine calls 1983 “the year the computer moves in”.	5.4
1984	Apple releases the Macintosh.	Apple releases the Macintosh, the first product to popularise the use of a mouse as a control device.	5.4

5.4 1985–1990

Many of the trends above continued to develop between 1985 and 1990 (see Table 5.8 below). Both the record industry and the PC industry continued to grow in strength, largely independent of each other. The record industry remained in strong partnership with the consumer electronics industry, and this relationship was further strengthened with the creation of the compact disc, the major landmark development between 1985 and 1990. During this period, the recording industry continued to embrace digital audio recording tools, with the technology becoming cheaper, supplemented with the new introduction of digital audio professional-level music creation tools such as digital synthesisers and samplers. At the same time, more general computing precedents emerged for later developments. Tim Berners Lee created the hypertext protocol in 1989, and the development of digital audio compression techniques appeared to gain momentum, with the Digital Audio Broadcast project in Europe and the establishment of the Motion Pictures Expert Group (MPEG).

Table 5.8 Events related to digital audio

Date	**Event**	**Description**	**Case study section**
17 August 1982	Compact disc debut.	Sony and Phillips in partnership create the compact disc format. It is quickly embraced by the recording industry and subsequently by consumers. By 1985 terms like “avalanche” and “set to explode” are being used to describe the emerging consumer response to the CD.	6.1

1987	Sony purchases CBS Records.	In 1987, when six major record labels own approximately 90% of the historical catalogue of recorded music, consumer electronics giant Sony stuns the entertainment world by purchasing major label CBS Records, making Sony the first consumer electronics company to own creative content.	6.2
1984	Sony	Sony creates the Discman, a portable CD player, which becomes a successful extension of their Walkman brand.	6.3
1980s	New digital instruments.	The Fairlight digital sampler, released in 1979, is added to new instruments like the Yamaha DX7 and becomes a popular tool for professional and amateur musicians.	6.4
1980s	Professional studios.	Professional recording studios widely record digitally, with digital mixing and mastering equipment common. The Synclavia II (1985) offers a cheaper version of these capacities for professional musicians.	6.4
1980s	Personal computers.	PCs continue to gain significant capacity and incremental growth, with new developments such as the CD-ROM. A range of PC software for music also emerges (music notation, MIDI composers). With 8-bit audio capacity, computers are only capable of beep-style sounds popularised in video games.	6.5, 6.6
1988	MPEG formed.	MPEG is formed in 1988 and charged with the task of developing compressed video and audio standards for multimedia technology such as the CD-ROM. In 1989, MPEG calls for standards submissions and receives 14. One such submission is from Karlheinz Brandenburg and others at the	6.7

		Fraunhoffer Institute; it later forms the basis of the MP3.	
1989	Chippy Hoax	British TV show *Going Live* broadcast an April fool's joke describing 'The Chippy' a computer chip the size of a credit card that stores hundreds of songs	6.8

5.5 1991–1994

The early 1990s represent a continuation of many of the previous themes and events (see Table 5.9). There was a growing proliferation of CD formats, leading to new levels of success for the recording industry as the CD became an increasingly strong and embedded technology. At the same time, personal computers continued to advance in capacity. The availability of the CD-ROM, the creation of the HTTP protocol, early analog-to-digital (and digital-to-analog) PC sound cards, precedent work on file compression standards, and file sharing on FTP sites all occurred at this time, leading to increasing recognition of the PC as a multimedia tool. Amongst these developments, other events and paths appeared, such as Sony's release of the MiniDisc, Phillips and Matsushita's digital cassette, IBM and Blockbuster's experimenting with in-store kiosks, and high level industry discussion about and recognition of the potential for looming dramatic change due to digital distribution.

Table 5.9 Record industry – CD sales continue, new technologies explored

Date	**Event**	**Description**	**Case study section**
1991	CD sales	With the falling cost of CD players and increasing catalogue availability, consumer adoption of the format is rapid. In 1991, CD sales surpass vinyl and cassette for the first time.	7.1
1992	Growing music industry awareness of coming change	The Home Recording Act was passed, and with this announcement the then head of the RIAA, Jason Bergman, announces a new threat: "The digital transmission of sound recordings is no longer science fiction, nor is it the technology of the future. It is here now. It is being advertised, it is for sale, and it is here to stay. Digital	7.2, 7.3

		transmission of music through cable, telephone wire, satellite, and broadcast will transform the way music is delivered to the home. It will transform the music industry as we know it, and it could soon entirely displace the sale of sound recordings to the public".	
1993	IBM/Blockbuster in-store delivery	IBM and Blockbuster create a kiosk system where consumers can create personalised CDs of major label songs. It receives no support from the recording industry. MCA Music Group chairman Al Teller states: "We will not, under any circumstances, license our music for use in any system of which we are not proprietors. We in no way, shape, or form support this venture, and I mean that unequivocally". Other labels also note their disapproval at not being consulted: "No one representing either Blockbuster or IBM has approached WMG to discuss obtaining our permission to reproduce our copyrighted works".	7.4
1992	Sony MiniDisc and digital cassette tape	In 1992, Sony releases the MiniDisc format, hoping to reinvent the industry once more. At the same time, Phillips and Matsushita create the portable digital cassette. Both of these technologies are described in *Billboard* as having the potential to shift the music industry once again.	7.5
1992	Release of MPEG Layer 3	Karlheinz Brandenburg and others at the Fraunhoffer Institute create and release the audio protocol MPEG Layer 3. Little adoption of the format occurs to begin with due to limited PC performance.	6.7, 7.7

Personal computers had largely been used for word processing and similar business tasks. With the new availability of a number of different hardware components such as sound cards, CD-ROM drives, and higher performing processors, PCs began to be seen speculatively as media tools. Multimedia became a topic in the music industry, and a range of new products emerged from entrepreneurs and artists exploring the domain (see Table 5.10).

Table 5.10 PC technology – new media capacities emerge

Date	Event	Description	Case study section
1989	Tim Berners Lee creates hypertext transfer protocol.	In 1989 Berners Lee creates HTTP, setting the foundation for the modern internet.	7.7
1990	Sound card technology.	Prior to 1990, PCs were limited to making polyphonic beep tones. This changes with the release of the Creative Labs Sound Blaster sound card in 1990. For the first time, the PC can play recorded music.	7.6.1
1993	FTP sharing of music, leading to Internet Underground Music Archive.	University of Santa Cruz computer science student Jeff Patterson, of the band the Ugly Mugs, buys encoding software and digitises his band's demo songs, uploading them to an FTP site. Overnight, people from around the world download the music, revealing to Patterson and friend Rob Lord a profound new capacity of the internet. With another friend, John Luini, the three soon set up the Internet Underground Music Archive, a website where bands can send in music for the group to digitise it and make available.	7.7
1993	CD-ROM with CD-authoring capacity, sound cards.	At the beginning of 1993, fewer than 500,000 PCs have CD-ROM drives. The first CD-RW drives are also released in 1993 but remain expensive and complicated. Sound cards also are not yet common.	7.6.1, 7.6.2
1994	Multimedia	By 1994, there is a growing awareness of the PC's capacity for "multimedia" and "interactive" content; it becomes a strong theme in parts of the record and PC industries. Early pioneering artists such as Todd Rundgren, David Bowie, Peter	7.6.4

		Gabriel, and Thomas Dolby begin to explore interactive CD-ROMs.	

5.6 1994–1997

The key events between 1994 and 1997 primarily related to the growing capacity and proliferation of PCs (see Table 5.11). With the increasing performance and decreasing cost of sound cards, CD-ROMs, and the nascent internet, the PC began to demonstrate powerful performance as a media device. Whilst the PC was not initially created as a media device, the concept of “multimedia” that emerged in the early 1990s appeared to capture the widespread imagination of media industries. Amidst competing visions of the future, such as Sony’s MiniDisc and Digital Compact Cassette, it was the multimedia PC that became increasingly recognised (at least for a short time in this period) as the most promising direction for the music industry’s advance.

The emergence of other PC hardware and software in this period supplemented the prominent recognition of multimedia. It was between 1994 and 1997 that CD burners (PC optical drives with the capacity to copy CDs) and the consumer internet began to be important. CD burners decreased rapidly in price through this period and were on the cusp of widespread affordability by 1997. With respect to the internet, whilst it was new and uncertain as a consumer application between 1994 and 1997, there was a large amount of experimentation with music products and services online in this time. Online band marketing, music industry analysis websites, band websites established by fans, forum discussions related to music, and preliminary attempts at music distribution over the internet all occurred in this period. The source of this experimentation was varied, from individuals and small startup companies to small and major record labels.

For those in the music industry, the changes brought with them uncertainty. In contrast, for advanced computer users, almost without trying, their PCs now had the ability to digitise, distribute, and listen to music – soon, almost any recording from the entire history of recorded music. Whilst this capacity didn’t become widely distributed until the emergence of mp3.com and Napster in the next period, it is in this one that the direct precedents to these events emerge.

Finally, it was also in this period that prototype portable digital music players first emerged. Whilst no portable digital music player was yet released by the end of 1997, the prototypes that emerged in this time highlighted the future possibility of this type of technology.

Table 5.11 PC technology as recognised media tool

Date	Event	Description	Case study section
1995	Multimedia capacity becomes increasingly standard for PCs.	1994 is recognised as a year of posturing and positioning by PC manufacturers as PC prices of PCs reduce and media capacity becomes standard. Media becomes an advertised character of PCs: “Compaq’s Presario line is billed as a CD player, video game machine, answering machine, speaker phone, fax – and oh yeah, computer – all in one box. All for under $1900” (Gillen, 1995, p. 90).	8.1
1994-1997	Forecasts for CD burning increase.	CD burning is still a niche activity but was forecast to become a mainstream behaviour before 1998 due to “plummeting drive prices and inexpensive, well designed software” (Louderback, 1995). By the end of 1996, drives breach sub-$400 retail prices for the first time, a 10-fold decrease from 1994 (Atwood, 1996, p. 64).	8.2
1993-1997	Consumer internet.	Between 1993 and 1997, the consumer internet comes alive. In January 1993 there are 1.3 million U.S. internet users. By July 1997, that number increases to approximately 19.5 million. Total users double every 12 months between 1993 and 1997.	8.3
1997	PC as a music tool.	Professor Brandenburg describes when the MP3 and the PC became popular: “At that time [1992–1995], the complexity was still too high for widespread application for distribution and so on. It was really once every PC was fast enough on one hand, and did have the soundcard built in on the other hand, that this [mp3/digital music] really took off. And that again technically was the case in 1995, but, really the	6.7, 7.3, 7.7

		avalanche was going in 1997". *(K. Brandenburg, personal Communication May 27, 2013)*	

Reflecting the growing presence and capacity of the internet and PCs, there was a large amount of analysis and forecasting in the record industry regarding the impact of these technologies on the distribution of music. Whilst popular perspectives suggest the record labels were slow to identify the threat of the internet, in *Billboard* there was early recognition of the potential of digital audio and the internet to cause profound change to the record industry from industry leaders. Opinions of a range of prominent record industry leaders cited in *Billboard* in various articles between 1994 and 1995 highlight how the internet and, more generally, digital audio were viewed at the time. A selection of quotes from prominent Record Label executives cited in Billboard articles of the time are included below in Table 5.12.

Table 5.12 Opinions of record industry leaders in 1994

Executive	Insight
Gary Gersh, President, Capitol Records	"[The industry] is on the verge of a massive revolution that will rewrite the ways we receive and relate to all forms of entertainment." He says Capitol is using "all of the various technologies" to collect information each week to better market its records. He says Capitol localizes and micro-markets by cross-referencing the data. The label also relies on computer technology for its art department (for digital download and transmission of art files) and for improved communication between field and national staff" (Lieb, 1994).
Michael Schulhof, President, Sony Music	"The executive told retailers it takes a customer about one hour to drive to a music store, purchase a CD, bring it home, and put it into his or her player. The transmission of that same recording to the home via fiber optics – so-called 'music on demand' – will take less than five seconds" (Jeffrey, 1994, p. 6).

Executive	Insight
Peter Cox, Managing Director, EMI Music Publishing UK	"The potential is enormous. It's only a matter of time before other people take this on" (Clark-Meads, 1995, p. 12).
Danny Goldberg, President, Atlantic Records	"In general, I think these technological advances have served the music business wonderfully well … Each development in technology has caused a growth in our business and expanded music. … Suppose everything becomes cyberspace … People are still going to have to be experts at making things look interesting. There will be limitless options, so how will we market ideas? People can only look at a small fraction of the possibilities, so it will take a lot of strategizing about how to expose music" (Lieb, 1994).

Supporting this, there emerged a range of new products and behaviour that utilised the internet and software for audio- and music-related activities (see Table 5.13).

Table 5.13 PC technology – proliferating digital music capacity

Date	Event	Description	Case study section
1995	Internet radio.	Cybercasting and webcasting become an early use of audio over the internet. Approximately 50,000 people download the RealAudio player in the first two months of its release in 1995, and in September 1995 live audio commentary of the New York Yankees vs Seattle Mariners baseball game is streamed online using the software, leading to widespread recognition of this as a new capacity for the internet (David Letterman, for example, discussed the streaming event on his show at the time).	8.3

1995	Internet and music discussed on MTV.	MTV profiles music activity on the internet in a news segment. The segment discusses the popularity of major label artist webpages, where fans can get information about upcoming tours.	8.3
1994/1995	Major labels experiment with digital distribution.	The Geffen label begins to explore internet distribution. At the end of 1994, as part of the marketing promotion for the release of Aerosmith's latest album, Geffen offers users the ability to download a previously unreleased Aerosmith track. The technological limitations of the download process are cited as impacting consumer response: "getting it [downloading] took more time than it would have to catch a bus to the local record store (connect-time charges were, however, waived for the promotion)" (Gillen, 1994). Jim Griffen, the director of technology at Geffen Records, suggests that due to the limited sound quality of internet audio streaming at the time, the technology is not yet effective for the broadcast of music, but instead streaming is better suited to speech (Atwood, 1995).	8.4
1997	Major labels use the internet for increased efficiency.	Despite concerns and problems with the distribution of music, the major labels embrace the internet as an efficiency tool themselves. An article in *Billboard* on 23 August 1997 titled "Majors Cut Costs Via Industry-only Sites" (Atwood 1997) describes industry-only, password-protected websites established by Capitol Records and Sony Music that allow industry members from around the world, such as distributors and promoters, to access visual assets, graphics, and ad copy of bands for advertising and	8.4

		promotion, rather than this material being sent by post (Atwood, 1997).	

By 1997, the sentiment of some within the labels regarding the role of the internet had shifted somewhat. Perhaps as a measure of wider awareness, and whilst there was still a recognised sense of the internet as an important technology, there was also increasing recognition and description of the internet primarily as a new marketing tool for the labels rather than as a distribution tool. At the time a number of record label executives were cited in Billboard describing the virtues of the internet to help sell content. Table 5.14 offers these quotes from Billboard, with them also discussed in section 8.4 of case study.

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Executive	Insight
Kent Rippey, Atlantic Records	"The number of hits at Atlantic's Web site has exploded from slightly more than 2 million a month a year ago to more than 8 million [a month] now."
Mark Ghuneim, VP of Online and Emerging Technologies for Columbia Records Group	"The Internet is a key word-of-mouth marketing/ promotional tool."
Chris McQuown, Senior Director of New Media, Universal Music Group	"It [the internet] helps disseminate information to a potentially huge number of people in a relatively inexpensive way. And as more people get on, the value increases dramatically."

Along with music industry interest and use of the internet, 1994 to 1997 was an important time for music software and hardware. Utilising the growing capacity of PCs, with the availability of sound cards increasing, new software emerged to offer new ways to listen to and manage music. Table 5.15 describes some of the major software of the time.

Table 5.14 Music library software and online music search

Date	Event	Description	Case study section
1997	Winamp	Winamp becomes a popular early library software, with 3 million people downloading the software in 1997.	9.2.3
1998	Musicmatch Jukebox	With CD burning increasing, Musicmatch Jukebox emerges; it is the first ‘complete’ software that offers uses tools to manage their digital music library on their pcs, as well as create playlists, and also easily burn CDs. Brandenburg refers to it as a landmark: “I think still MusicMatch is a milestone because they built the first software which bundled together ripping of a cd, mp3 encoding, and then having smart ideas about how to play it, having it organized and so on.” (Professor K. Brandenburg, personal communication, May 27, 2013).	9.2.3
1999	Online MP3 searching	With the popularity of MP3s, a range of online websites emerged that focussed on helping users find them. Scour.net, mp3meta, and Mp3.lycos are leading MP3-file search engines and indexes (*PC Computing*, 1999), and it is the later unreliability of these services that prompts Shawn Fanning to create Napster.	9.2.4
1997	Online piracy	Online piracy is becoming a significant problem for the recording industry. Software and music is shared in new Internet Relay Chat groups like the popular Warez.	9.2.4
1997	Mp3.com	Reviewing popular search terms, entrepreneur Michael Robertson recognises that the term ‘MP3’ is growing in popularity. Not knowing what it is, Robertson buys the domain mp3.com for	9.6

		$1,000, turning it into an information website about the format and how to download music. Within the first 24 hours, and with no marketing, the website has 10,000 unique visitors. Robertson goes on to build mp3.com into a powerful company.	

Amongst these developments, the first prototype portable digital music players were created using flash memory (see Table 5.16). The technology had limitations, and the price/performance characteristics still made the players experimental, but they did offer a tangible new technology of the future. At the same time, other technologies such as MiniDisc and Digital Cassette represented more viable paths, but they had not yet received significant adoption.

Table 5.15 New technologies, including prototype portable digital music players

Date	**Event**	**Description**	**Case study section**
1994–1997	MiniDisc/DAC	MiniDisc and Digital Cassette (DAC) are the latest technologies to attempt to transform the record industry. Whilst these technologies have popularity in some markets (such as Japan), by the late 1990s it becomes increasingly clear that both MiniDisc and Portable Digital Cassette weren't becoming the widespread media devices that manufacturers had hoped. The narrative in *Billboard* started to change, going from describing the technology as one with widespread potential to supersede the CD to relegating the technologies to a niche popularity (Christman & Jeffrey, 1997; McClure, 1999).	9.3 (Sony section), 11.3.6
1994	NEC Silicon Audio	In 1994, the large electronics company NEC announced a prototype portable digital music player that used flash memory called Silicon Audio. The flash memory	8.5

		cards could hold 32 MB of data (two to three songs).	
1996		Almost two years after NEC's Silicon Audio device, on 23 September 1996, Audio Highway, a small startup company based in Cupertino (Silicon Valley), announces the Audio Highway Listen Up Player, a 32 MB player that connects to the internet overnight to download content. It is shown at the Consumer Electronics Show.	8.5
1997	AT&T FlashPAC	In a similar guise as the NEC Silicon Audio player, in 1997 AT&T announces plans for their own flash-based audio player. The AT&T FlashPAC will utilise Perceptual Audio Coding, developed at AT&T Bell Labs (Onufryk & Snyder, 1997). Whilst details of the player are not readily available, and it does not reach production, the player is profiled in a CNN Business Week segment on music on the internet, on 3 July 1997. No other information appears available, and no device is released.	8.5
1997	Hard drive systems	Radio stations begin implementing hard drive storage for their music libraries. 1997 is described in the article as an important threshold year for these systems. Whilst available from the early 1990s (originally as 1-2 GB systems), by 1997 a range of entrepreneurial companies (e.g., Broadcast Electronics, ENCO Systems, RCS, and Computer Concepts) are selling larger 9 GB hard drive systems. The market leader is Broadcast Electronics, which has 25% to 30% of the market share, with their 9 GB AudioVAULT system retailing for $20,000 (Traiman, 1997). Despite the cost, radio stations particularly view the systems as	8.5

		cost-saving measures by saving on duplicate CD purchases.	

5.7 1998–1999

During the previous section, increasing power and proliferation of PCs and the internet began to reveal a clearer capacity for digital music distribution, with sparks of niche interest by the end of 1997. Between 1998 and 2002, these and other factors ignited. In a staggering sequence of developments, many occurring concurrently, the recording industry – and it could be argued consumer electronics and computer industries – began to be reconfigured around new digital music computer software and hardware technology. It was between 1998 and 2002 that most of the events or technologies emerged for the transition from widespread CD distribution to internet-based music distribution. In this four-year period, the following things happened:

- The top selling year for CDs of all time was 1999, after which CD sales began to recede dramatically;
- The RIAA and over 200 member companies from consumer electronics, computing, and the record industry formed a large industry group called the Secure Digital Music Initiative (SDMI), attempting to create a piracy-resistant digital music format (and ultimately disbanding after Napster);
- "mp3" became the most popular search term on the internet in 1998 and grew in popularity between 1999-2001;
- The major labels partnered with IBM to trial a new digital distribution system called the Madison Project prior to Napster;
- Napster was released and became widely popular, leading to a dramatic confrontation with the record industry and making digital music a source of widespread international cultural intrigue;
- A large amount of entrepreneurial experimentation emerged in digital music products such as library software, peer-to-peer products, and digital music hardware, and this was complemented by a large amount of press coverage of digital music events;
- Some of these entrepreneurial companies such as eMusic and mp3.com briefly became billion-dollar companies after capturing the peak of the 1999 Nasdaq bubble;

- Entrepreneurial companies could not yet gain legitimate competitive licenses from major labels, with litigation being a common occurrence between the RIAA and entrepreneurial companies;
- The first portable music player using flash memory was released and was soon followed by a raft of other players from companies such as Diamond, Creative, and Sony;
- Researchers at Compaq established a new category of portable player, creating the first portable music player using a computer harddrive.
- After all of this, and using a great deal from this previous experimentation, in 2001 Apple released iTunes then 8 months later, the iPod.

If these events occurred over a wider timeframe, they would remain dramatic. But amplifying their intensity, many of them emerged at the same time. As such, whilst it is difficult to separate out events that emerged together, to better cover the detail of the above, these events have been split into two smaller sections, one covering 1998–1999 and another covering 2000–2002, with some overlap between the two. The following will begin with 1998 and 1999 (see Table 5.17).

Table 5.16 PCs, the internet and music

Date	**Event**	**Description**	**Case study section**
		By 1999, the personal computer is almost 20 years old. It has become a common device, with almost 50% of U.S. homes having a computer by 2000 (U.S. Department of Commerce, 2011, p. 7).	9.1
1999		Internet use continues to proliferate quickly, moving beyond niche demographics to become a common tool (Pew Research Centre, 1999), with a particularly sharp jump in use occurring in 1998. Of those respondents in the survey, 46% have started to use the internet consistently for the first time in 1998 (Pew Research Centre, 1999). High speed	9.1

		internet (broadband) also becomes increasingly common at universities.	
	E-commerce	Reflecting this, in 1998 and 1999, e-commerce fever strikes the industry. A survey of senior executives from the world's 525 largest companies suggests that e-commerce is now a major strategic imperative (Electronic Commerce News, 1999).	9.1
1998	iMac	On 6 May 1998, Apple releases the iMac. It is the first product launch by Jobs (and Ive and Rubinstein) since returning to the company as CEO (interim CEO at the time).	9.2.1
	CD burning	In 1998 and 1999 CD-R drives become increasingly standard PC hardware as blank discs fall in price. A single blank CD-R disc capable of holding up to 650 MB of data, which previously cost upwards of $10, has decreased to $2 by 1998 (Somogyi,1 September 1998; Frost, 1998).	9.2.2
5 October 1999	iMac DV, release of iMovie	Jobs announces and updates the iMac with a focus on digital video (iMac DV) and iMovie, a new Apple software for desktop video editing to be used in conjunction with Apple's Firewire transfer standard. The iMac DV and iMovie release is a prequel to Apple's more complete digital hub strategy that is announced a little more than a year later. But, with this release in 1999, Apple's strategy now is on a more direct path towards media, even if not yet focused on music.	9.2.1, 10.1.4
		In October 1999, "mp3" becomes the most popular search term on the internet (Jones & Sul, 1999).	9.2.4

		Despite this, there remain acknowledged frustrations with download speed, and these were discussed in *Billboard*: "Practical obstacles, chiefly bandwidth, stand in the way. MP3 music files are just too big for speedy download from the Web at conventional modem dial-up speeds of 28.8 kbps or 56 kbps. (Another reason why I find CD-ripping rather than Web downloads so much more gratifying)" (Lewis, 15 August 1999). Some specific timed examples: "The 49.41 MB Liquid Audio down-load would take about 15-16 minutes with a T1 connection but more than 2 hours with a 56K modem" (Gillen, 2000b).	

Despite the growing prevalence of MP3 downloads, CD sales continued to crescendo in this period rising from 753.1 million CD unit sales in 1997 to 847 million in 1998. They increased further in 1999, with 1999 becoming the top selling year for CDs of all time, with a total of 938.9 million CD albums and 55.9 CD singles being sold (RIAA, 2016). Despite this background of the most lucrative years of the CD format and music industry as a whole, the uncertainty regarding the capacity of the internet as a tool for music distribution was quickly evaporating. Online music purchases jumped 400% between 1997 and 1998 to $142.9 million (Dyson, 1999), and whilst this was a microscopic figure in comparison to CD sales and even smaller as a percentage of the $38 billion value of the music industry worldwide (New Media Age, 1999), the growing public awareness and experimentation with MP3 and the significant amount of entrepreneurial activity, as well as forecasts for online music to be a $1.1 billion market by 2003 (Atwood, 1999), was enough for the labels to initiate more substantial experimentation into online distribution.

With the five major labels owning approximately 80% of the entire recorded music catalogue at this time (including the music from almost all high-profile artists; Dyson, 1999), the major labels still represented a large and critical element that was missing from online music; with their control, they represented an important authority in determining the direction that online music distribution would take. There was not yet any way for the public to legitimately buy and download music owned by the major labels. Online music distribution up until this point was centred upon content from independent musicians, music downloads for sale licensed legitimately from small labels, and major label songs and albums that were transferred to MP3 and shared illegally by consumers. But there was now a significant amount of entrepreneurial experimentation and discussion offering new products based on these new technologies. Within this context, the major labels explored a number of avenues for online distribution prior to the release of Napster.

First, working in secret in early 1998, two of the major labels, Warner Music and Sony Music, initiated a partnership with IBM to explore and create new online music distribution software. The partnership between the labels and IBM became known as “the Madison Project”, and its mandate was to create a software program that would give consumers at home access to download major label catalogue albums. The software would allow PC users to download albums via the internet, and the software itself would explore features such as watermarking and encryption to prevent individuals from sharing music illegally (Price, 1999).

When the plans were revealed publicly in mid-1998, it was described in the press as “one of the most ambitious tests of digital music distribution to date” (Rawsthorn, 1998), and the partnership between the world’s biggest computer company and, for the first time, major music labels who controlled mainstream music content was described as a significant step forward. The partnership was also a strong signal from IBM about the role they saw music having in the emerging commercial capacity of the internet. It was reported in a variety of sources that IBM invested $20 million in the project to build the software (Chadbourn, 1998; *IBM Computer Today*, 1999; Rawsthorn, 1998; Chadbourn, 1998). The software was tested on 1,000 homes in San Diego and allowed users to purchase and download major label albums. The test was described as a success, but during the trial the major labels began to explore a number of other avenues.

Second, and at the same time as the Madison Project in late 1998, a large-scale trade group called the Secure Digital Music Initiative (SDMI) was established by the RIAA, representing the major labels. SDMI was established with the aim of creating a secure digital music format to replace MP3 that made piracy difficult. Creating a digital distribution system that included security measures would potentially provide record labels a way to build an online business model comparable to their CD channels, intercepting the staggering growth of the unsecure MP3 format.

The announcement of SDMI occurred at Sony Music’s New York headquarters on 15 December 1998 and included some of the most powerful individuals and companies in the recording industry, including RIAA President/CEO Hilary Rosen and then Vice President Cary Sherman, International Federation of Phonographic Industry (IFPI) Chairman Jason Berman, BMG Entertainment President/CEO Strauss Zelnick, EMI Recorded Music President Ken

Barry, Sony Music Entertainment Chairman/CEO Thomas D. Mottola, and Universal Music Group Chairman/CEO Doug Morris (Reece & Jeffery, 26 December 1998). Over the next two years, SDMI worked on the task, culminating in the release of a technical standard with strong built-in protection and sharing restrictions. Once released (which occurred after the emergence of Napster), Stanford computer science professor Ed Felten cracked the secure standard, rendering the piracy controls ineffective and leading to the suspension of the SDMI program. These events, independent of and preceding Napster, demonstrated both the experimentation and uncertainty of the time. Table 5.18 outlines these key events.

Table 5.17 Record labels, RIAA, SDMI

Date	**Event**	**Description**	**Case study section**
1997–2001	Litigation	With prominent examples of unauthorised use, litigation is a prominent response from the RIAA on behalf of the major record labels.	9.4.1
June 1999	Madison Project	IBM spends $20 million on the development of a prototype home PC delivery software, partnering with the major labels. A 1,000-home experiment in San Diego is run in June 1999. The trial is described as a success, with users buying and downloading albums, but the program does not progress.	9.4.2
1999	Small-scale downloading experimentation.	Other small-scale experimentation also occurs. Before the end of 1999, Atlantic Records releases the single “Bliss,” by Tori Amos, as a digital download for sale, Virgin Records offers David Bowie’s new album, *Hours*, as a downloadable purchase prior to its in-store release, Platinum Records offers Pete Townsend’s live album for free download, and TVT Records announces plans to make their entire catalogue available for download (Gillen, 1999).	9.4

December 1998–2001	SDMI	Led by Leonardo Chaglioni, and with over 200 member companies, including all the major labels, consumer electronics, and IT companies, SDMI is a working group that attempts to create a secure music format to counter online piracy. A standard is created but soon cracked, and in 2001 the effort is suspended.	9.4.3
	CD revenue, CD singles and albums	Eclipsing cassette sales for the first time in 1991, CD album sales grow dramatically through the rest of the 1990s, reaching unprecedented heights in 1998 and 1999, both with respect to the volume of sales (peaking at 938.9 million shipped units in 1999- RIAA, 2016). CD albums have become the dominant format and revenue source, with CD singles not available for some popular titles.	9.4.4

In March 1998, the first generation of portable digital music players was created and sold to the public, moving beyond the preceding prototypes and demonstrations. The first ever recognised portable player released for sale to the public was the MPMan, created by Korean company Saehan. Within a few months, there emerged a range of similar flash memory portable music players from a variety of companies. The major success was the Diamond Rio, which dominated the early market (Sullivan, 1999). Despite the success of Diamond, there was a great deal of uncertainty regarding the direction of the technology and the market. Early players caused some frustration for users with poor design or technological performance constraints (such as limited memory capacity 32 or 64 MB flash cards). Equally, SDMI, the record industry's attempt to establish a secure format as a legitimised alternative to MP3, was being coordinated at the same time, causing industry uncertainty with respect to the direction of the software standard for digital music. Whilst small early companies initially prospered, and whilst Sony had uncharacteristically missed the start of the market, there was a general expectation that they would come to dominate the portable digital music player market. Sony entered the market with the release of their player in late 1999 (over 18 months after the first players). Contrary to expectations, the Sony player received sharply negative consumer feedback, leaving the direction of the technology once more uncertain. Table 5.19 describes the events related to portable music players of the time.

Table 5.18 The first commercially released Portable Digital Music Players

Date	**Event**	**Description**	**Case study section**
March 1998	Saehan	Korean company Saehan releases the MPMan, a 32 MB flash memory player.	9.3
May 1998	Diamond	Diamond released the PMP 300, with, similarly, 32 MB flash memory, running off a single AA battery, and with a retail price of $200. Diamond is quickly sued by the RIAA for vicarious copyright infringement.	9.3
1998–1999	Sony	In 1998, the same year as the above portable music players were released, Sony spends $30 million advertising their MiniDisc format. It is the biggest advertising budget for any product in their history. The following year, on 21 December 1999, Sony then enters the portable digital music player market, releasing the Sony Memory Stick Walkman. It is based around Sony's memory stick flash format and requires music to be formatted using Sony's proprietary ATRAC music format. Naively, the player cannot play MP3. As a result, it receives widespread criticism and is largely derided by consumers.	9.3
July 1999	A growing range of players.	An increasing volume of players from a variety of companies become available. Samsung, Audio Vox, Sensory Science, and Creative, among many others, all release similar players in this time.	9.3
June 1999	Expected consumer response.	Forecasts emerge of expected rapid uptake of MP3 players, suggesting that within eight months approximately 1 million MP3 players will be sold (New Media Age, 1999).	9.3
October 1999	Compaq	Compaq engineers create the Compaq Personal Jukebox PJB-100. A brand new	9.3

		design utilises a computer hard drive rather than flash, shattering previous storage limits. Where flash memory was constrained to 32 MB (8 to 12 songs), the PJB-100 has a 4.86 GB hard drive, capable of holding 1,000 songs. Despite creating the device, Compaq does not pursue the category, licensing the design to a company called HanGO.	

All of these events were dramatic, but they were soon to be eclipsed. In 1999, Shawn Fanning created Napster. Its release caused a dramatic, unprecedented new development for the record industry, revealing a new powerful capacity of the internet. Napster is covered in significant detail in the case study (section 9.7), including the creation, release, popularity, lawsuit, impact, and outcomes. But, Table 5.20 outlines the growth in users to demonstrate the sheer and striking scale of consumer response to the product.

Table 5.19 Napster user growth

Date	**Approximate time since launch**	**Number of Users**	**Key event**	
June 1999	Beta launch	30	Fanning sends out the beta link to 30 friends, mainly on IRC (particularly the w00w00 channel), instructing them to not send out the software to anyone else.	(Ante, 2000)
June 1999	2 days after	3,000–4,000	IRC users do not follow Fanning's directive, and a few days later, there are 3,000 to 4,000 users.	(Ante, 2000)
August 13th	Official release	Undisclosed	John Fanning (co-founder/Shawn's uncle): "It has been hugely successful … We have doubled in size for the past five days".	(in Lemos, 1999)

Date	**Approximate time since launch**	**Number of Users**	**Key event**	
November 1999	4 months	100,000	"Napster already had two hundred thousand registered users offering 3.5 million files. All of that, without having spent a dime on marketing".	(Menn, 2003, p. 98)
January 1999	5 months	150,000	Napster CEO Eileen Richardson: "It took ICQ 14 months to get to where we are in only six months" (Levy, 2000).	(Menn 2003, p. 113; Levy, 2000)
May 2000	9 months	11 million	Reaches top 10 in internet search terms. An estimated 73% of students have used it (estimated total college students, 15.31 million).	(Walsh, 2000)
July 2000	11 months	20 million downloads, 4 million daily users, 500,000 concurrent users	Recognised as "The fastest ramp-up of a user base in Internet history".	(Napster, 2000)
October 2000	16 months	35 million	Napster continues its rapid trajectory.	(Menn, 2003, p. 252)
February 2001	19 months	Estimated peak: 85 million (2 million concurrent users; Aydar, 2005)	"The fastest growing internet application of all time" – 3 billion files being traded per month (Murray, 2007, p. 184).	(Aydar, 2005; see also Greenman, 2002, p. 802)

The record industry was now under siege from digital technology. At the same time, with annual CD revenues over $900 million, there was now legitimate uncertainty regarding immediate survival.

5.8 2000–2002

Digital music had progressed significantly from earlier times. The forecasts of the role of the PC as a multimedia tool that were common between 1994 and 1997 had disappeared by 2000. Intel's 1997 advertisements announcing that the PC had a media capacity had also stopped. It was entirely obvious at this point that the computer was a powerful media device, and with the dramatic amount of developments between 1998 and 1999, even within the now overheating internet bubble, the *Wall Street Times* announced, "Music is the hottest commodity in the digital world" (Peer, 2000).

Despite the dramatic number of developments, in this time there was not yet any one obvious direction music would take. Litigation resulted in a brief reprieve. Napster was shut down in 2001, mp3.com was sued, and, after this, in 2000 and 2001, the direction and path of digital in many ways had become more opaque rather than more obvious in the wake of these services. The piracy threat that had been eased by the capitulation of Napster escalated once more as Kazaa and other second-generation peer-to-peer services quickly eclipsed Napster's size.

The major labels themselves became particularly busy through this time. It was a heavy time of jockeying for position by the labels themselves, with acquisitions of entrepreneurial businesses common at the same time as further experimentation in new products. As the labels engaged, perceptions of the entrepreneurial environment were also changing. Michael Robertson, for example, who was an adamant and vigorous competitor to the record labels until this time, had sold mp3.com to Vivendi Universal, the biggest record label in the world, and now Robertson worked for them.

Despite the experimentation, this period ended with online distribution remaining elusive for the major labels; their own distribution services initiated in this period, MusicNet and Pressplay, eventually failed. By the end of 2002, there remained no user-friendly way to purchase all major record label content on the internet. Table 5.21 describes these issues.

Table 5.20 Major record label developments

Date	**Event**	**Description**	**Case study section**
2001	Napster	Napster court case ends, Napster is shut down due to inability to filter out copyright material and dwindling numbers.	9.7
2002-2003	Kazaa	Second generation peer-to-peer software emerges, with Kazaa being the leader. It quickly eclipses Napster. Sixty-four million	10.1.3

		download the software in 2002, with over 227 million copies downloaded by May 2003. Kazaa and other second-generation peer-to-peer services like Grokster are sued in 2003.	
July 2000	Senate hearing	Led by Senator Orrin Hatch, a Senate judiciary committee is formed to investigate why entrepreneurial companies couldn't get licenses from the major labels.	10.2
December 2001-January 2002	MusicNet and Pressplay	MusicNet and Pressplay are announced by the major record labels. These are online services offering major label content for stream and download for a monthly fee. These services encounter problems of antitrust, as well as poor reviews from consumers, and never receive significant adoption.	10.3.2

This was also a dramatic time for the portable digital music player market. Experimentation expanded, and there was a proliferation of portable digital music players from a variety of consumer electronics and computer companies.

Memory capacity remained a problematic characteristic of players, and in this time there more clearly emerged two distinct categories of portable players with different types of memory. The first was a flash memory-based portable player following on from previous designs of the Diamond Rio and MPMan. These players were extremely light and small, but commonly had a capacity of 32-64 MB, capable of storing 6 to 12 songs. The second category was a hard drive-based "jukebox" player, following the PJB-100 from Compaq. These players utilised laptop hard drives that offered massively increased capacity but were bulky and not easily portable. These players commonly had a 4.86 GB capacity, capable of holding 1,000 songs.

Of these categories, the smaller portable flash memory players were the dominant category, with almost all active manufacturers adopting this design at this time. Jukebox players in contrast were viewed by consumers as useful, but too big to be portable, and there were a relatively small number of manufacturers offering these types of products.

For both categories, though, despite the large volume of activity, no particular player had emerged as dominant. Small players like Diamond (by this time renamed SonicBlue) had some early success, but large companies like Sony had been consumer disappointments, meaning that there remained uncertainty regarding whether the technology itself would be adopted, and, if so, at what scale. As Steve Jobs soon would say, despite a large number of products available, of these companies “no one has found the recipe” (Jobs, 2001). The events are summarised in table 5.22.

Table 5.21 Ongoing Portable Digital Music Player experimentation

Date	**Event**	**Description**	**Case study section**
2000/2001	Large range of competitors offering Portable digital music players	The 2000 and 2001 Consumer Electronics Shows are described both as a “frenzy” and an “explosion” of activity with respect to portable digital music players, with the announcement of a “dizzying number of next-generation players” (Garrity, 2001; Gillen, 2000).	10.4
2000/2001	Flash memory was viewed as critical.	Flash memory is increasingly supported by the industry, despite current limitations of cost/storage performance. Players of 32 and 64 MB are most common, capable of holding 6 to 12 songs. With falling prices expected, flash is the popular memory of most players. For example, after surveying the available players on CES, one record industry executive says: “I have seen the future, and it has a flash-card slot in it” (Gillen, 15 April 2000).	10.4
	Forecasts	In 2000 approximately 880,000 players are sold (Garrity, 2001). Short-range forecasts suggest the market will grow by 54%, with 1.8 million units sold in 2001 (Garrity, 2001); middle-range forecasts expect the market to reach 15 million users by 2003 (Marriott, 2000); and long-range forecasts predict that by 2005 the digital music market will be worth $3.2 billion in annual revenue, with 26 million to 37 million digital audio devices sold annually by this time (Gillen, 2000a; Shim, 2001).	10.4

2000	Hard drive Jukebox players	After the PJB-100, a range of new hard drive players are released, establishing the jukebox player as a more definitive category. The Creative Nomad Jukebox and the Archos Jukebox are leading alternatives, utilising 4.86 GB laptop hard drives.	10.4
2000	IBM Microdrive	By 2000, IBM increases the capacity of its small Microdrive to 1 GB whilst maintaining its very small size dimensions, and with this, it comes to be recognised as a significant development for portable music players (Menta, 2000b). Retailing for $499, the 1 GB capacity hard drive offers the capacity to store over 300 songs, far exceeding flash capacity for the same price; also, in contrast to jukebox hard drive players, Microdrive offers light-weight portability.	10.4

It was in this period that Apple engaged in digital music. They released iTunes in January 2001, and then followed this 10 months later with the release of the iPod in October 2001. Both iTunes and iPod's creation are covered in detail in the case study, highlighting and exploring the choices Apple made to draw in available components from external vendors, as well as apply their own sensibilities to create the device. Table 5.23 describes Apple's engagement in digital music.

Table 5.22 Apple and digital music 2000–2001

Date	**Event**	**Description**	**Case study section**
2000	CD-RW	The iMac is a leading computer and has a focus on digital video, but it does not yet contain a CD-RW drive. In contrast, for PC manufacturers CD-RW drives have increasingly become a standard component. By this time in 2000, almost 30	11.1.1

		million PCs have been sold, with CD-RW drives as standard.	
2000	First iMac with CD-RW drive	Seeing the dramatic consumer uptake of CD burning, Apple transfers their focus from digital video to music: “I felt like a dope,” says Jobs, thinking back to summer 2000, when his fixation on perfecting video editing on the Mac distracted him from noticing that millions of kids were using computers and CD burners to make audio CDs and to download digital files called MP3s from illegal online services like Napster. “I thought we had missed it. We had to work hard to catch up” (Schlender 2001).	10.1
9 January 2001	Digital hub strategy	Jobs announces the digital hub strategy, recognising the role of the PC as a hub for portable digital media devices, such as cameras.	10.1.4
9 January 2001	iTunes	In the same keynote as the digital hub strategy, Jobs announces the release of iTunes. iTunes, like MusicMatch, offers a complete experience as a music library and includes ripping and burning software. Apple advertises this capacity with their popular “Rip. Mix. Burn.” campaign.	10.1.4
23 October 2001	iPod	With a development process of approximately eight months, and drawing together their expertise and available components from external suppliers, Apple creates the first iPod, a 5 GB hard drive player reaching a storage capacity of 1,000 songs. This eclipses the 6 to 12 songs of flash players, and, with new components and design, Apple has been able to also make the device portable, with a much smaller profile than other jukebox players.	10.5

23 October 2001	iPod reaction	There is a mixed reaction to the announcement of the iPod. The press reviews it positively, but, in consumer forums, many view it as an expensive imitation of the many available products already on the market (King & Manjoo, 2001); for example, "No wireless. Less space than a Nomad. Lame" (Slashdot.org 2001).	10.5
9–14 November 2001		As iPods become available to consumers, however, there is a more positive assessment in forums from those that try the device: "Now everybody's getting more into it's now that they realize the potential of this device" (Macrumors.com, 2001).	10.5

5.9 2002–2008

The story from 2002 onwards becomes the story of iPod. The iPod became a worldwide consumer phenomenon comparable to Sony's achievement with Walkman, but at a significantly larger and faster scale. In 2007, the final full year of this study, 52.6 million iPods were sold, responsible for 72.4% of all portable digital music player sales (Krazit, 2007). The iPod has subsequently been recognised as an iconic device, winning awards such as "gadget of the decade" and "best device of all time" in the technology press (Malik, 2007; *Wired*, 2009).

This level of success was not cast or obvious with the first iPod model released in late 2001. Instead, Apple's success between 2002 and the start of 2008 emerged as a result of new development and strategy. In this time, Apple pursued an aggressive product strategy, bifurcating iPod from a single product into a product range with a number of models, along with a constant stream of updates with improved performance. Added to this, Apple released iTunes on the Windows platform (the first Apple software ever released on Windows), and then Apple partnered with the major labels to create the iTunes Music Store, which itself also became a consumer phenomenon and established the first significant online revenue source for the record industry.

These events are chronicled in detail in the case study, along with a number of events that emerged as a result of the impact of the iPod, including sharply receding CD sales leading to closures of CD retailers and a change in the entrepreneurial environment as the iPod became a dominant design (see Table 5.24).

Table 5.23 Apple and digital music 2002–2008

Date	**Event**	**Description**	**Case study section**
2003–2008	Record industry transformation	Label revenues from CDs recede quickly, and the record industry changes. Major record merchandisers begin to suffer significantly. Famous businesses like Virgin Megastores and Tower Records are sold off or bankrupted.	11.1
28 April 2003	iTunes Music Store	Apple reaches a landmark agreement with the major labels to begin offering their songs for sale. The iTunes Music Store is a dramatic success. In the first 18 hours online, approximately 275,000 tracks are sold at a cost of 99 cents per download (Newman & Garrity, 2003, p. 80). By the end of the first week, 1 million tracks have been sold (Knopper, 2013). The consumer response to a legitimate download service requiring payment is a staggering development in the context of the time. To give perspective, the combined total of downloads on other legitimate download services was approximately 1 million tracks sold in the previous two years (Newman & Garrity, 2003, p. 80).	11.2
2003–2008	Portable music players	After the emergence of the first iPod, there is a significant shift in characteristics of the portable digital music player market. iPod first dominates the jukebox category, and then with the iPod Mini and Nano comes to dominate the flash memory category too. Apple dominates the entire market. Major new entrants such as Microsoft fail to make an impact on Apple's success. Flash manufacturer Sandisk emerges as the	11.3

		second most successful company due to their price advantages with flash. Manufacturers that survive begin to focus on niche audiences.	
2003–2008	Sony	Sony remains bereft in the portable digital music player market. Viewing the iPod in 2003, Keiji Kimura, senior VP at Sony, said, “We do not have any plans for such a product … But we are studying it”. By 2005, the head of Sony’s Computer Entertainment Division, Ken Kutaragi, acknowledged publicly that the company had made some major mistakes and admitted they should have released the iPod themselves (Menta, 2005). Sony release a range of products aimed at niche audiences. They also release their Playstation Portable, which does not have significant impact on iPod sales.	11.3.6

The above casts the backdrop to the larger narrative of this time, which was the progression of the iPod from initial technology to worldwide phenomenon. The iPod is covered in detail in the case study, including the strategic decisions of Apple through this time, reflections on the achievement of the iPod from those involved in its development, as well as how Apple built on the initial advantage to achieve outright domination of the portable music player market as it transitioned from a small niche consumer category to a widespread mainstream audience. Whilst the case study covers a great deal about Apple’s iPod strategy at this time (section 11.4), the impact of this strategy is summarised in table 5.25, which describes iPod sales per year and cumulatively through this time.

Table 5.24 iPod sales per year

Year	Yearly iPod unit sales	Cumulative iPod sales
2001	125,000	125,000
2002	570,000	695,000
2003	1,451,000	2,146,000

Year	Yearly iPod unit sales	Cumulative iPod sales
2004	8,263,000	9,714,000
2005	31,960,000	40,223,000
2006	46,432,000	86,655,000
2007	52,685,000	139,340,000
2008	55,434,000	194,774,000

The increase in iPod sales was also a result of the strong bifurcation strategy at this time, as Apple moved the iPod from a single product to a range, with a number of different models with different pricing and features. Overlaying the sales of iPod with the release of these models in Figure 5.1 demonstrates the change in consumer response as new iPod models were released.

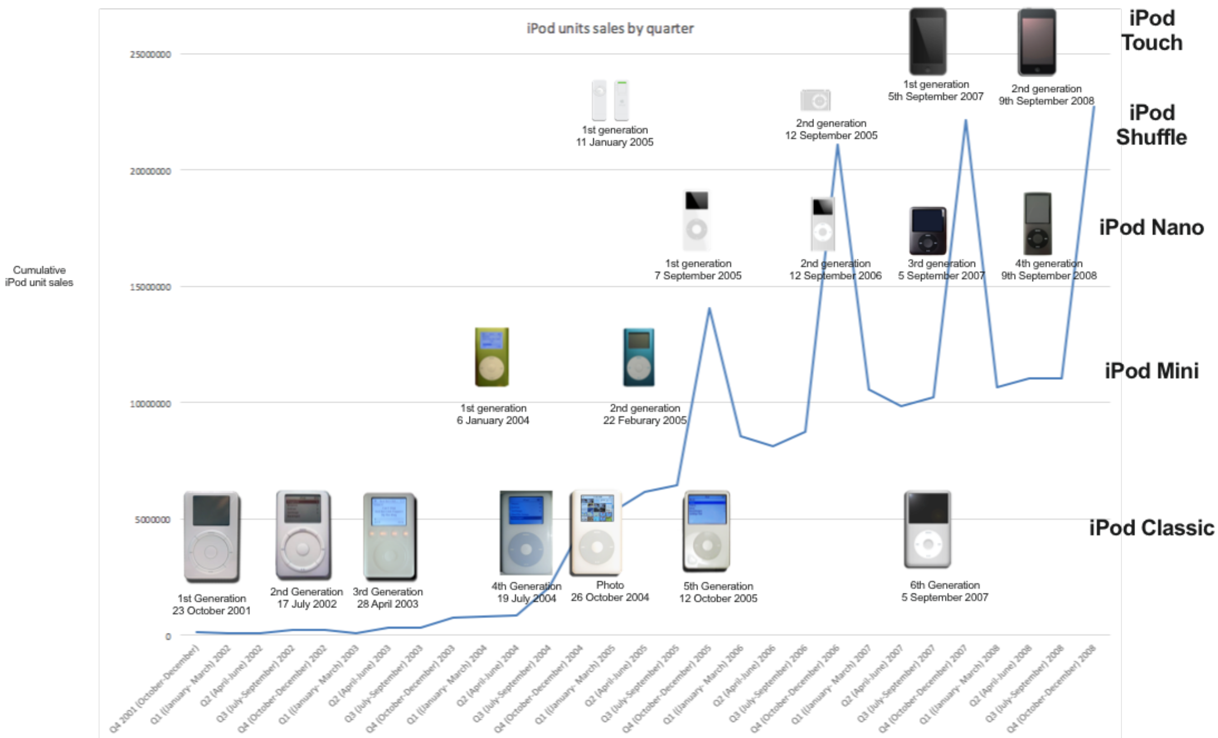


Figure 5.1 iPod unit sales per quarter, overlaid with iPod product releases

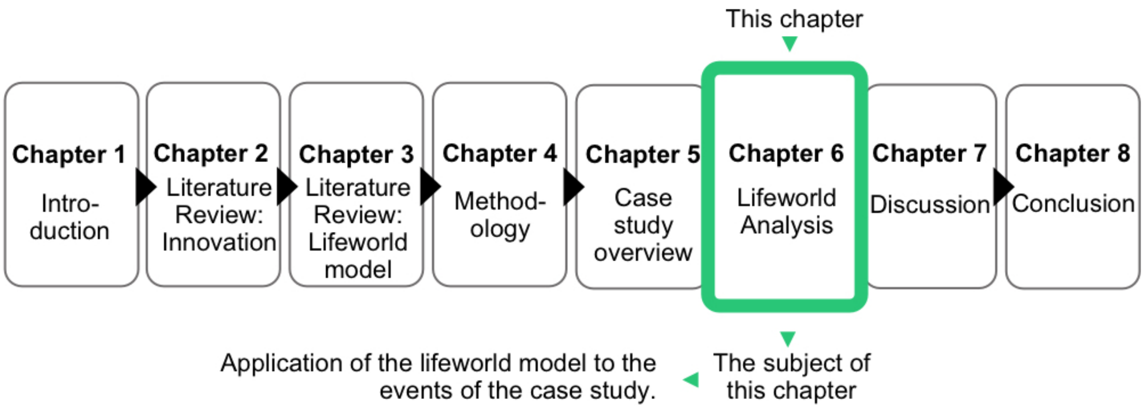
The case study ends in 2007, with Apple dominating the portable digital music player category. In 2007, Apple also released the iPhone, which soon had a noticeable impact on iPod sales. The top selling year of iPod of all time was 2008, after which sales began to recede as the iPhone began to emerge as another powerful consumer success.

5.10 Chapter Summary

This concludes the summary of the case study of portable digital music players. Using both primary interviews and extensive secondary data, the case study provides a very detailed chronological overview of events related to portable digital music players from pre-1877 through to 2008, with a main focus on events between 1994 and 2007, when the most tangible activity occurred. Over this time, the portable digital music player developed from imaginative description to early prototype and became a product of widespread experimentation from a large variety of entrepreneurs and, finally, found a dominant consumer product in the iPod. Whilst the amount of detail in the case study is extensive, and the timeframe broad, this detail now provides a basis for application of the lifeworld model from chapter 3. The next chapter will also utilise the case study, but now will describe these events through the four alternative lifeworlds, exploring how the likelihood and possibility of innovation in portable digital music players changed over time.

Chapter 6

Lifeworld Analysis



6.0 Introduction

This chapter presents the case study application of the technology lifeworld model. It details the development of portable digital music player technology applying the lifeworld model from chapter three. It begins with the prehistory lifeworld, describing the conditions prior to the emergence of the first portable digital music players. The establishment lifeworld is then presented, which describes the lifeworld where the first portable digital music players were created. This is followed by the development lifeworld, where a large number of new entrants is expected, leading to significant variation and selection. It then finally presents the innovation lifeworld, where innovation is finally achieved.

The detailed case study to support this analysis chapter is presented as a separate volume. This volume provides a detailed chronological event history narrative of personal digital music players constructed for this research. This analysis chapter will draw from this event history narrative, making reference to particular sections of the case study, which can be referred to for greater detail.

Along with the presentation of the markers of each lifeworld, this will also include an analysis of events and the likelihood of innovation at different times. The prehistory lifeworld will now be discussed.

6.1 Recap of the lifeworld concept

The lifeworld concept which was described in chapter 3, describes the need to view innovation as both more than a consequence of heroic individuals with great ideas, as well as the limits of innovation systems, recognising that the need to identify strong boundary conditions to use a system, may miss the vital essence of what creates innovation itself. It describes how the conditions of innovation change over time, and how these conditions impact the likelihood of success. The lifeworld concept describes four separate lifeworlds, from prehistory, to innovation that represent the different conditions that characterise the development of a technology.

The rest of this chapter, will apply the lifeworld concept to the case study, documenting and categorising the events of the case study of portable digital music players, into the four lifeworlds that describe how conditions of innovation changed.

6.2 Prehistory lifeworld

The first lifeworld is described as the prehistory lifeworld, where the technology is not yet possible. The lifeworld is not advanced enough to provide component technologies of creation. Despite this, in this prehistory lifeworld, there may be imaginative descriptions of the potential technology or failed attempts to build it using incorrect technology. Overlaid in this same lifeworld there is expected to be a pre-existing parallel technology that is in a mature state of normal science (Kuhn, 1962) with strong socioeconomic alignment. Providing the capacity to recognise this lifeworld for a particular technology, a number of markers were offered in the model chapter. These are repeated in Table 6.1:

Table 6.1 Prehistory lifeworld markers

Marker 1	It may be possible to identify imaginative descriptions of the technology.
Marker 2	These imaginative descriptions reveal an inability to create the technology.
Marker 3	There may be a history of discontinuities of similar forms of parallel technologies.

Marker 4	There is expected to be a particular strong parallel technology that later the new technology will compete against.

These markers will be now be discussed and applied to the case study.

6.2.1 **Marker 1: It may be possible to identify imaginative descriptions of the technology.**

In exploring the prehistory lifeworld of portable digital music players, there were a number of references in science fiction and a number of “technological visions” from musicians and entrepreneurs who identified the potential to create portable digital music devices long prior to the capacity emerging to create them.

In science fiction there were a number of early references to “recorded music” prior to any technology making this possible. Francis Bacon in *New Atlantis* (1626) wrote of the concept of recorded music and generally synthesiser music, referring to “soundhouses” where recorded music could be listened to by the public. Equally, Bellamy (1888), in a book called *Looking Backward, 2000–1887* (1888), describes ubiquitous recorded music as a fundamental characteristic of the future (or “utopia” as he referred to it; case study reference section 2.0). These descriptions don’t directly describe portable music players, but they do offer imaginative description of the general concept of recorded music prior to technologies emerged to do so.

There also exist some more specific fictional forecasts of portable and computer music. In 1953, Ray Bradbury published the novel *Fahrenheit 451* (Bradbury 2012). Within the book, Bradbury describes “seashell radios”, electric ear-bud-style music devices that allow individuals to isolate themselves from the external world and listen to music (http://technovelgy.com/ct/content.asp?Bnum=456). With respect to computer music too, in June 1950, four years after the initial development of ENIAC (first digital computer; case study section 4.5) and before development work occurred on tangible computer music technology, Kathleen Maclean published a science fiction story called “Incommunicado” that described computers as music instruments. The short story was published in *Astounding Science Fiction* and was also the focus of the cover illustration of the issue (Figure 6.1).

Figure 6.1 Computer music described in Astounding Science Fiction

Closer to the emergence of portable digital audio devices, but still preceding them, a number of more specific fictional descriptions of portable digital music players were available. These descriptions appear to fit Basalla's concept of "technological visions" (1988) and were not part of stylised narratives such as those of science fiction described above but instead those of particular individuals, such as entrepreneurs, musicians, or record label executives, who attempted to articulate new portable music products based around digital technology. These forecasted products will be described individually.

6.2.1.2 1979

In 1979, a British inventor named Kane Kramer drew a digital music player and in-store delivery system (see case study section 5.5). Recognising the impact of counterfeit vinyl records, Kane Kramer believed a solution was to build a system that sent music down the telephone line, for record stores to then program to audio to tape for in-store customers. He saw this as a way to make sure all record stores would always have stock. He produced a seven-page report detailing the advantages for music retailers. He also provided diagrams of what the concept would look like (Figure 6.2):

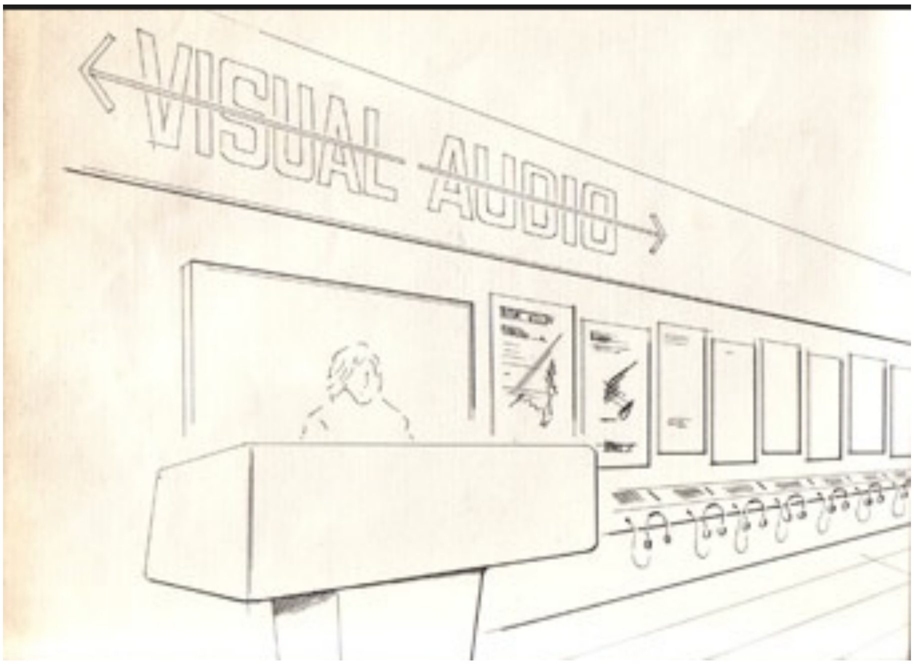


Figure 6.2 Kane Kramer's Digital music player in-store delivery system

Working for some years on these concepts, in 1981 Kane Kramer also produced a portable digital music player concept.

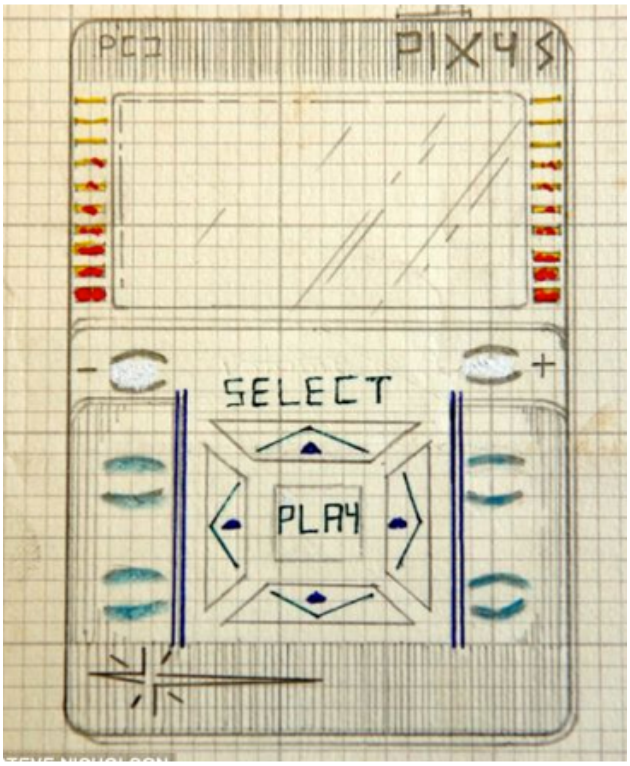


Figure 6.3 Kane Kramer's Portable digital music player concept (IXI) of 1969

Kane Kramer attempted to build a company to sell the product. He also registered patents for the audio-limiting means for digital audio. However, within a number of years, the company failed, and the patents became public domain after Kane Kramer later failed to renew them. These became public domain prior art, and in 2006 when Apple was taken to court for patent infringement by a company called Burst.com, Apple flew Kane Kramer to California to be a defence witness, highlighting some technical similarity between the iPod and the IXI player. Kane Kramer describes the similarity:

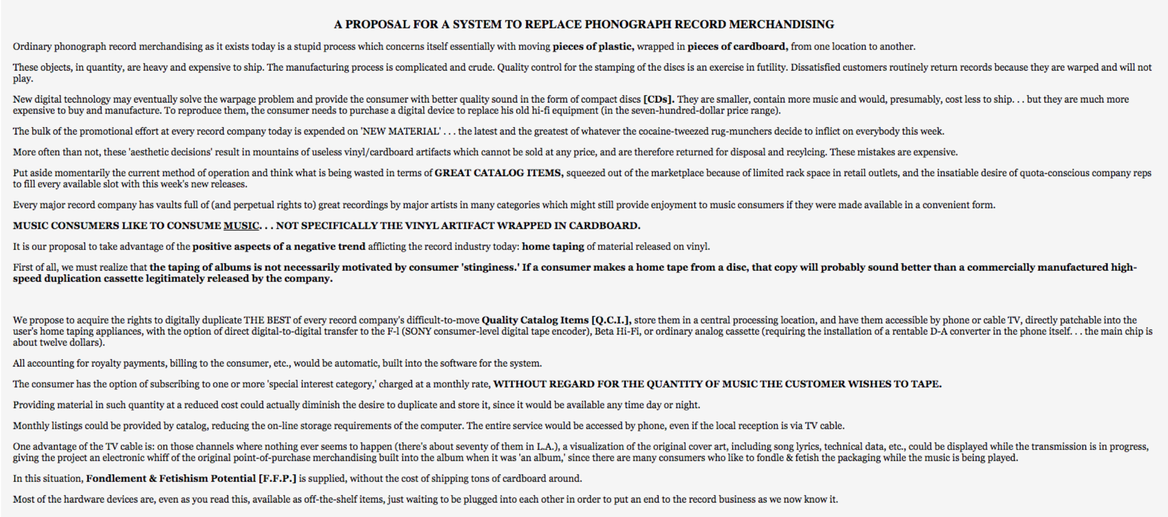
> There's lots of aspects to do with iTunes and the iPod itself. From how it digitises music, how it lays it into memory. How it overcomes certain problems to do with the fact that electricity moves far quicker than we want. So if you were to play a track back without using limiting means you would hear the track, it might be a 3 and half minute track but you'd hear it in half a second. So to actually slow that down, those mechanisms. I've also drew the actual device, the style of the device, the four way scrolling control. I mean certainly if you took everything out that I did back then, [comparing to the iPod] what you'd have is a plastic box probably that didn't play anything today. (Kramer, 2004).

6.2.1.3 1989

In 1989, the British children's TV show *Going Live* broadcast a segment as an April Fools' joke (case study section 6.8). The segment described a new portable personal music player called "The Chippy" that people would soon be able to buy in stores. The Chippy was described as a computer chip (hence the name) no bigger than a credit card that could store hundreds of songs, offering users the ability to play back any song instantly. Viewers were invited to call in and request a song, and host Phillip Schofield said that soon artists' entire back catalogues would be available on the device (Townsend, 2011). Schofield revealed to viewers that the segment was an April Fools' joke, but the subsequent development of MP3 offers many of the same characteristics described in the Chippy segment.

6.2.1.4 1990

Apart from the above specific predictions and forecasts of digital music players, there were also a number of forecasts about the concept of home delivery of music and the impact it would have on the record industry. Frank Zappa was a prominent musician who described this. Like what motivated Kramer to explore the concept, Zappa described the problems of the existing technology of vinyl records and CDs, and suggested a more advanced system of sending music to consumers via telephone lines (Figure 6.4).



A PROPOSAL FOR A SYSTEM TO REPLACE PHONOGRAPH RECORD MERCHANDISING

Ordinary phonograph record merchandising as it exists today is a stupid process which concerns itself essentially with moving **pieces of plastic,** wrapped in **pieces of cardboard,** from one location to another.

These objects, in quantity, are heavy and expensive to ship. The manufacturing process is complicated and crude. Quality control for the stamping of the discs is an exercise in futility. Dissatisfied customers routinely return records because they are warped and will not play.

New digital technology may eventually solve the warpage problem and provide the consumer with better quality sound in the form of compact discs **[CDs].** They are smaller, contain more music and would, presumably, cost less to ship. . . but they are much more expensive to buy and manufacture. To reproduce them, the consumer needs to purchase a digital device to replace his old hi-fi equipment (in the seven-hundred-dollar price range).

The bulk of the promotional effort at every record company today is expended on 'NEW MATERIAL' . . . the latest and the greatest of whatever the cocaine-tweezed rug-munchers decide to inflict on everybody this week.

More often than not, these 'aesthetic decisions' result in mountains of useless vinyl/cardboard artifacts which cannot be sold at any price, and are therefore returned for disposal and recylcing. These mistakes are expensive.

Put aside momentarily the current method of operation and think what is being wasted in terms of **GREAT CATALOG ITEMS,** squeezed out of the marketplace because of limited rack space in retail outlets, and the insatiable desire of quota-conscious company reps to fill every available slot with this week's new releases.

Every major record company has vaults full of (and perpetual rights to) great recordings by major artists in many categories which might still provide enjoyment to music consumers if they were made available in a convenient form.

MUSIC CONSUMERS LIKE TO CONSUME MUSIC. . . NOT SPECIFICALLY THE VINYL ARTIFACT WRAPPED IN CARDBOARD.

It is our proposal to take advantage of the **positive aspects of a negative trend** afflicting the record industry today: **home taping** of material released on vinyl.

First of all, we must realize that **the taping of albums is not necessarily motivated by consumer 'stinginess.' If a consumer makes a home tape from a disc, that copy will probably sound better than a commercially manufactured high-speed duplication cassette legitimately released by the company.**

We propose to acquire the rights to digitally duplicate THE BEST of every record company's difficult-to-move **Quality Catalog Items [Q.C.I.],** store them in a central processing location, and have them accessible by phone or cable TV, directly patchable into the user's home taping appliances, with the option of direct digital-to-digital transfer to the F-l (SONY consumer-level digital tape encoder), Beta Hi-Fi, or ordinary analog cassette (requiring the installation of a rentable D-A converter in the phone itself. . . the main chip is about twelve dollars).

All accounting for royalty payments, billing to the consumer, etc., would be automatic, built into the software for the system.

The consumer has the option of subscribing to one or more 'special interest category,' charged at a monthly rate, **WITHOUT REGARD FOR THE QUANTITY OF MUSIC THE CUSTOMER WISHES TO TAPE.**

Providing material in such quantity at a reduced cost could actually diminish the desire to duplicate and store it, since it would be available any time day or night.

Monthly listings could be provided by catalog, reducing the on-line storage requirements of the computer. The entire service would be accessed by phone, even if the local reception is via TV cable.

One advantage of the TV cable is: on those channels where nothing ever seems to happen (there's about seventy of them in L.A.), a visualization of the original cover art, including song lyrics, technical data, etc., could be displayed while the transmission is in progress, giving the project an electronic whiff of the original point-of-purchase merchandising built into the album when it was 'an album,' since there are many consumers who like to fondle & fetish the packaging while the music is being played.

In this situation, **Fondlement & Fetishism Potential [F.F.P.]** is supplied, without the cost of shipping tons of cardboard around.

Most of the hardware devices are, even as you read this, available as off-the-shelf items, just waiting to be plugged into each other in order to put an end to the record business as we now know it.

Figure 6.4 Frank Zappa's Proposal for a System to Replace Phonograph Record Merchandising

These are the imaginative descriptions that were identified in the case study that preceded the emergence of portable digital music players.

Marker summary

The case study revealed a number of imaginative descriptions of portable digital music technology, with these forecasts preceding the technology itself, often by a large margin. The below will analyse these descriptions in greater depth with reference to the achievement of innovation, using other markers.

6.2.2 **Marker 2: These imaginative descriptions reveal an inability to create the technology.**

Comparing forecasts to the eventual emergence of portable digital music players, the above technological forecasts are vague in detail. Science fiction descriptions of the "seashell radio" of Ray Bradbury do not specifically reference any type of technology apart from electricity. Another discussed above, the "Chippy", offered a description of a "computer chip" and a concept of size – "no bigger than a credit card that could store hundreds of songs" – but with no description of the specific mechanics of the technology. Both of these descriptions are void of technical specifics (which is not a criticism), due to their emergence in science fiction or children's TV.

Kane Kramer's IXI player drawings could be viewed initially as the counterpoint to this absence of detail. Kramer registered patent on parts of his device (the audio limiting means), and more recently this design of Kramer's has been acknowledged by Apple in their defence argument against another company's patent infringement. This has led to recent suggestion of Kramer's design being the determinant of the iPod: "Apple admit Brit invented iPod" (Boffey, 2008).

Kramer himself suggests a particularly strong link with his initial design and that of the later emergence of the iPod:

> I mean certainly if you took everything out [of the iPod] that I did back then, what you'd have is a plastic box probably that didn't play anything today. (Kramer, 2004)

However, there was a clear lack of capacity to create Kramer's device in 1979–1982, and Kramer's work remained an impossible technology of the time. Looking at technologies that were missing at the time that later emerged, reveal a clear absence of capacity that Kramer was confronted by. For example, there was yet no consumer internet, digital audio standards such as the MP3 had not yet been created, and computer components were bulky, with the concept of a personal computer only starting to emerge in the public domain. When pressed in an interview, Kramer himself also gave insight into the limitations of technology at the time, and whilst suggesting many of his ideas were similar to the iPod, he more objectively identified the impossible constraints he was facing at the time too:

> "In any event, even if you had put a digital audio player in the hands of every man, woman, and child on the planet, they couldn't have done much with it, because no one had digital audio tracks yet; the studios didn't have any digital audio mastering equipment" (Kramer 2004).

This insight is consistent with the concept of a prehistory lifeworld. The lifeworld does not yet provide conditions that allow for the creation of the technology in focus, and imaginative descriptions of the technology have little effect on binging this capacity forward.

The above examples identify that whilst there existed imaginative forecasts of technology, these were constrained to imagination, with actual creation impossible. They did not initiate the technology and had little if any influence on the later development of the technology itself.

How do these technologies get so close?

If it is clear that so many of the later important enabling technologies of digital music were not available at the time, it also appears important to consider similarities. These imaginative forecasts do offer some similarity to eventual technology like iPod. Most specifically, Kane Kramer's IXI player drawings from 1979 does appear similar in some ways the later successful iPod. It appears important to analyse this – how did these forecasts achieve similarity to later technology, despite the inability to build these technologies at the time?

It is suspected that the accuracy of Kramer's forecasts particularly, as well as other concepts such as Frank Zappa's description of home delivery, appear at the time more referencing the problems and limitations of the existing technologies of the time, including vinyl, cassette, and CD distribution rather than effectively describing the emergence of a new technology to solve these problems.

Both Kramer and Zappa had expert-level familiarity with the problems of music distribution at the time. Describing the motive for the creation of his drawings, Kane Kramer identifies that his brother was the manager of Olivia Newton John at the time, and they were struggling with the problems of counterfeiting and returns of vinyl records. As a direct response to this, Kramer conceived of sending music down a telephone line, which was the catalyst Kramer identified for the creation of his IXI concept. Zappa too as a major-label musician appears to describe the problems with shipping of vinyl records, titling the manifesto "a proposal for system to replace phonograph recording merchandising", focusing much of the discussion on problems with "back catalogues". This description appears insightful and detailed regarding the limits and problems of merchandising, revealing a capacity to see the limits of the technology of the day as the driver of how they identified new technologies to overcome these limits.

In contrast to their detailed understanding and description of the problem though, when describing the new technology both Zappa and Kramer use to address these issues, both Kramer's and Zappa's descriptions start to become vague or inaccurate. Zappa suggests that digital distribution is possible by using generic detail of "software" and "requiring the installation of a rentable D-A converter in the phone itself", which misses a great deal of the detail and technical components that were required to make digital music work- the diffusion of personal computers (discussed in case study section 4.4, 5.1, 5.5, 5.6, 6.6, 7.1), the emergence of the internet (case study section 7.3, 8.2), the creation and proliferation of PC sound card technology (case study section 6.6.2), multimedia performance capacity of PCs (case study section 6.6.4), music on the internet (case study section 6.7), Napster (case study session 8.5), and Kazaa (case study section 9.3.1) all occurred prior to the creation of the subscription services of MusicMatch and PressPlay (case study section 9.3.1.1), which offer a direct comparison to the subscription concept of Zappa. Each of these technologies and developments had their own trajectory, were often contested and emerged often in an unexpected manner. With his forecast being made before these events, Zappa was not aware of all of this experimentation and technology prior to it occurring, and his technology forecast did not have this detail embedded within it, rendering it limited in all but the problem side of the forecast. The same can be said of Kramer – his drawing appears similar to the iPod, but his drawing lacks almost all of the detail that would allow Kramer to turn the product into an actual device, including all of the technical components of the iPod (detailed in case study section ##).

The forecasts of Kramer and Zappa focus more on problems with existing technology and also use the technology available at the time to address them. This available technology available at the time represented constraints that no imagination could breach, rendering the products of Kramer and Zappa impossible. Perhaps the best way to articulate this issue comes from another expert interviewed for this study- Jeff Paterson, the creator of the IUMA (Internet Underground Music Archive- one of the first places to download music from the internet). Patterson describes the motivations for creating IUMA, identifying that whilst there was a grand vision, it was pragmatically using what was available at the time that made IUMA work:

> *In the early days, I think there was a group of us that all had this idea of the celestial jukebox – access your music anywhere, any track, anything, and the middle-class musician – where anyone can post their stuff and get reimbursed and make their living off their own self-promotion, so that was like, we think that's utopia. That's where we want everything to be, and then we have these tools in front of us right now, so how can we use them to get us one step closer. And create glimpses of it right now, where if you have things configured properly, even, yes, you could get music on the go? (Jeff Patterson, personal communication June 26, 2013).*

This identifies that, in this case, imagination is driven by looking past the current limits of technology, and using whatever means within reach to offer an alternative to them. A similar insight was offered by William Gibson, who, whilst providing the description of cyberspace, also acknowledged more recently how much it was different to the eventual later creation of the internet:

> When people write imaginary futures they're never about the future. They can only be about the moment in which they are written, and the known history before that. We don't have anything else. We have no access to the future. We can try to extrapolate and we can spin scenarios and try to make future histories that seem intriguingly logical, but they aren't going to be anything like what really happens. (Gibson, 2014)

Overall, it appears imaginative descriptions in the prehistory lifeworld are more useful for revealing limits to existing technology of the time, rather than being insights into future technology. These imaginative forecasts reach beyond the capacity of the prehistory lifeworld, and whilst they hint at a possible future, it is one of many alternatives, with no obvious likelihood that these imaginative descriptions will later be either a technology or innovation.

6.2.3 Marker 3: There may be a history of discontinuities of similar forms of parallel technologies.

The other element of the prehistory lifeworld is dedicated to discussion of existing technologies of the lifeworld. The model chapter identified that for the technology in focus, there may be a history of discontinuities (Tushman & Anderson, 1986; Anderson & Tushman, 1990) – previous technologies that offer a similar form of consumer value. An example is the progression of airplanes from propeller piston engines to turbine jet engines (Constant, 1980). In isolation each technology is discontinuous; in sequence they represent a lineage of tools for flight.

The recording industry had just such a history of discontinuities, with a sequence of key technologies over time. Jac Holzman, the founder of Elektra Records, said with respect to the technology of the record industry in 1979: “The record business has always been in transit” (Holzman, 1979; case study section 5.3), and certainly throughout its over 100-year history there has been a number of key technologies. Vinyl records, cassette tapes, and compact discs represent the three major paradigms of the music industry in its history prior to the emergence of internet-based distribution and portable digital music players. The case study documents the history of these three technologies extensively (see case study section 3.0, 3.1, 4.2, 4.8, 5.2, 6.1, 8.3), as well as the recording industry more generally. These technologies over the course of 100 years built up the recording industry to be powerful one, with each technology building on the previous to achieve new levels of success. Figure 6.5 from the RIAA charts sales from 1973 highlighting the strength of vinyl, cassette tape, and then compact disc technologies as well as the transition that occurred between them (RIAA 2016).

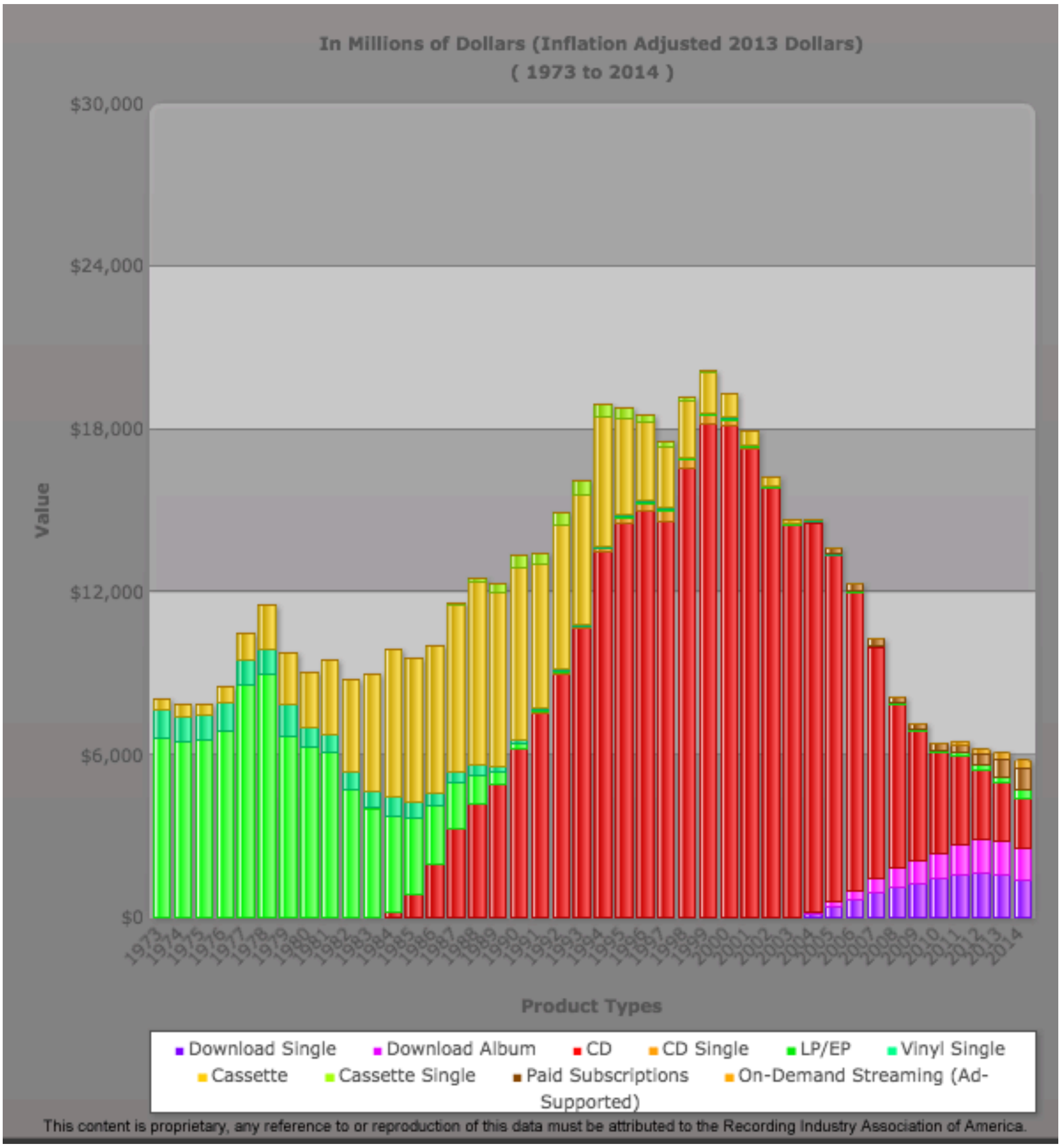


Figure 6.5 The history of various music format sales from 1973 onwards

With reference to the emergence of digital music technologies, and particularly portable digital music player technologies, these preceding technologies represent a history of development and investment in alternative technologies that occurred prior to the emerge of portable digital music technology. Similar to Arthur's concept of technological lock in (*##), these technologies provided a context that later influenced and constrained the development of portable digital music technology.

6.2.4 Marker 4: There is expected to be a particular strong parallel technology which later the new technology will compete against.

In the prehistory lifeworld of portable digital music players, the record industry was a strong industry built around compact disc technology. The CD, which debuted on 17 August 1982 (case study section 5.1), fast became a powerful technology eclipsing sales of both vinyl records and cassette tapes for the first time in 1991 (case study section 6.1). This would be a parallel technology to the eventual release of portable digital music players, and by the first time the portable digital music players were released in later lifeworlds, the CD was strong, with the recording industry coordinated as a range of elements, including manufacturers, logistics, distributors, and retailers, as well as support such as marketing and design, all dedicated to CD technology. The CD technological paradigm played an important role in the emergence of portable digital music players in coming lifeworlds, which will continue to be explored.

If viewing the lifeworld, it is important to note that they are overlapping in some way, whereby, in this case, the prehistory lifeworld of portable digital music technology, is also the maturity lifeworld of CD technology.

6.2.5 Prehistory lifeworld summary

This concludes discussion of the prehistory lifeworld. Summarising this lifeworld, there does not yet exist capacity to build the technology. Imaginative descriptions of portable digital music players were created, but these did not result in specific technology and are of little to no subsequent value with respect to the development of the later innovation. These forecasts fail because of what is missing from the detail of their descriptions; there is a lack of accumulative capacity, and these forecasts, whilst acknowledging limitations of existing technology, also overstate the current capacity of available technology for innovation. The lifeworld is also configured around an existing technology; in the case study, this was compact disc technology, which was a powerful technology improving in sales throughout the 1990s. It is from these conditions that the next lifeworld will be discussed.

6.3 Establishment lifeworld

The second lifeworld is the establishment lifeworld. In the establishment lifeworld, the first products are offered, establishing the domain in focus. Compared to the prehistory lifeworld, accumulation has advanced to a point where there are now components that make it possible to create the technology in focus. Despite the emergence of these technologies, it is expected that they do not achieve significant innovation due to the adolescence of technology, lacking performance and the strength of parallel technologies.

The model chapter described the establishment lifeworld with a focus on accumulation leading to opportunities for new combination. It was described that the establishment of a technology is dependent upon the availability of components, and accumulation in performance available technologies will lead to the capacity to establish the technology in focus. With a focus on this accumulation, combination, and exaptation, the model chapter offered these four markers of this establishment lifeworld (see Table 6.2).

Table 6.2 Establishment lifeworld markers

Marker 1	The domain will be established with the release of a new product.
Marker 2	The new technology can be described as a combination of pre-existing technology.
Marker 3	The component technologies that are utilised will have a traceable history in other domains.
Marker 4	There are some tangible new performance characteristics of these component technologies that make the new technology possible.
Marker 5	The new technologies will emerge as adolescent with limited performance and will now compete against a parallel technology in a stronger state.

These markers will now be explored individually.

6.3.1 **Marker 1: The domain will be established with the release of a new product.**

In 1994, large electronics company NEC announced a prototype portable digital music player called Silicon Audio, with the device profiled in a range of sources, including *Financial Times*, *Billboard*, *Popular Science*, and minidisc.org. The device was described as the first computer-chip-music idea to reach a working level (Woudenberg, 1995). It used the newly developed flash memory format to store music on self-contained cards. These memory cards (pictured in yellow in Figure 6.6) could hold 32 MB of data, and using the NEC-recommended MPEG layer 2 audio compression format, this was advertised as approximately 24 min of audio. The memory cards were then insertable into the Silicon Audio portable music player, which was the card reader (the purple and grey readers pictured in Figure 6.6). The price of the newly released flash storage was restrictive at the time, with a 32 MB card described to have a retail price of around $2,000. NEC identified that this pricing placed the device outside the reach of a consumer (and therefore was only created as a prototype), but they expected flash to decrease in cost, which would open up the consumer market: “NEC predicts, however, that 90 minutes worth of memory card capacity will cost approximately $100 by the year 2000; playback-only cards will cost even less” (Normile, 1995, p. 48).

Source: Woudenberg (1995), minidisc.org
http://www.minidisc.org/main_chip_music.html

Source: Normile (1995), Popular Science Magzine
https://books.google.com.au/books?id=m0FZFRNj9IYC

Figure 6.6 NEC: Silicon Audio Prototype

Almost two years after NEC’s Silicon Audio device, on 23 September 1996, a small startup company based in Cupertino (Silicon Valley) called Audio Highway announced the Audio Highway Listen Up Player (see Figure 6.7). Relying on technology and design common to cell/mobile phones of the time (such as display screens and black plastic design), the Listen Up Player was a portable digital sound device that included 12 MB flash storage. The device worked in conjunction with the Listen Up Player PC software called AudioWiz that downloaded audio (music and other audio content) from the internet and then allowed users to transfer this audio onto and off of the Listen Up Portable Player. The Listen Up Player also was suggested to have a battery life of 1 hr of continuous playing, making it a particularly portable device: “You can use it while you’re jogging, think of a Walkman for the internet” (Schulhof, 1998). The memory of 12 MB was a severe constraint, but one that reflected the cost of flash memory which, whilst still prohibitively expensive, had decreased significantly from the Silicon Audio prototype (Audio Highway, 1996). In 1997 the Audio Highway Listen Up Player won a Consumer Electronics Show innovations award, being described as a “big innovation in internet appliances” (Chiefet, 1997). Whilst the company contracted Fujistu to manufacture the device, only 25 units were ever released to the public (Ha, 2010).

Figure 6.7 Audio Highway Listen Up Player

In 1998, the first widely available portable digital music players were released. The MPMan by Korean company Saehan (see Figure 6.8) is largely recognised as the first MP3 player and was first sold to the public in March 1998 (Buskirk, 2005; Camerani, 2012, p. 63; Knopper, 2009, p. 166; Reece, 1998). It proved immediately popular with a niche audience of computer and music enthusiasts, with $30,000 worth of the players sold in the first three days of their availability online (Reece, 1998).

In May 1998, two months after the release of the Saehan MPMan, a new portable music player called the Diamond Rio PMP 300 (Portable Music Player) was released by a U.S.-based PC component company called Diamond MultiMedia (Knopper, 2009, p. 166) (see Figure 6.8). Diamond was an established company with a profile selling computer components such as modems, sound and graphics cards, and multimedia accelerator cards (Wong, 13 January 1998; Reece, 1998). The Diamond Rio was described as an immediate sales success as soon as it entered the market in time for Christmas 1998 (Menta, 2003b), and whilst sales figures are difficult to find, it has been reported in a number of sources that more than 200,000 units were sold over the lifespan of the device (Ha, 2010; Knopper 2009).

Both the MPMan and the Diamond Rio had similar characteristics of 32 MB flash memory capacity, which was enough to hold approximately seven to eight songs at 128 kbps MP3 compression. The virtues of flash-based memory were an advertised feature of the Diamond Rio, with the PMP 300 promoted as having no skipping errors during playback, making it ideal for activities such as walking, running, and cycling (Reece, 1998). Other shared features include AA battery power, liquid crystal display, and plastic casing.

Figure 6.8 MPMan and Diamond Rio

These events will now be described with references to the markers offered in Table 6.2.

6.3.2 Marker 2: The new technology can be described as a combination of pre-existing technology.

The creation of the portable digital music player relied entirely on existing technologies available in 1997. Computers, as well as computing components such as memory, digital-to-analog converters, the internet, software (including MP3), components from the consumer electronics industry such as liquid crystal displays, as well as general precedents such as plastic and electricity, were all available in 1997 *before* the MPMan and Diamond Rio first were created. That is to say, the portable players recognised above, the Listen Up Player, the MPMan, and the Diamond Rio all are combinations of pre-existing technologies.

To contrast against the earlier prehistory lifeworld, many of these technologies weren't available in 1979 at the time of Kane Kramer's drawings for his IXI player. The lifeworld had changed; by 1998 a large number of new technologies emerged that hadn't been available in the 1970s. Whilst it is not possible to identify all preceding technologies in depth, the development that occurred in a number of these technologies will be further explored with reference to the coming markers.

These new technologies, whilst heralded as potentially dramatically new innovation, were created by applying familiar and available technological components. It was also the changing capacity of these components, such as the decrease in cost of flash storage, which also saw the shifting type of product that was introduced in this stage, moving from a costly prototype in the Slicon Audio Player, to the first small scale commercially successful portable player in the Diamond Rio. The trajectory of component technologies is a focus of the next marker.

6.3.3 Marker 3: The component technologies that are utilised will have a traceable history in other domains

The technologies utilised within portable digital music players had long trajectories of development prior to the creation of the first portable music players. During this time, the development of these component technologies occurred not for the specific intended purpose of digital music players. Drawing from the case study, there are many examples of this, but for efficiency the history of two central technologies will be explored prior to their use in portable digital music players: digital audio and the personal computer.

6.3.3.1 Digitalisation of sound

Reflecting on why he failed to create his IXI player in the late 1970s, Kane Kramer identified that at the time digital audio was not yet widely available, and the major recording studios did not yet have digital mastering equipment. In comparison, by the time the Diamond Rio was released in 1998, digital audio was common: the recording industry recorded digitally to compact disc, and “MP3” was a popular search term on the internet. Exploring the trajectory of digital audio during this time reveals characteristics that made it both impossible to create a portable digital music player in the late 1970s and likely in 1998.

Digital music began with the pioneering efforts of Max Mathews and others at Bell Labs in the 1950s, who used new IBM mainframe computers for the creation of music. The exploration led to the creation of the earliest digital music. It also influenced a number of subsequent developments, including the creation of Frequency Modulation synthesis by John Chowning, as well as offering precedent for the development of PCM analog-to-digital sound converters.

PCM is a technique that produces a digital form of audio signal from an analog source, and by 1969 both Sony and Nippon were selling PCM recorders to the professional music studio market (Baert, Theunissen & Vergult, 2013, p. 9). The quality of digital signal was described as higher quality compared to analog tape and, as a result, in the 1970s and 1980s there was an arms race as the major record labels embraced digital for this superior “pristine” audio quality characteristic (discussed in case study section 4.8, 5.3), fitting out a number of record studios with the advanced and at the time expensive digital audio technology. The rollout was slow due to expense, but by the 1980s the technology had become much cheaper and was increasingly utilised by smaller studios too.

With the availability of digital audio, there were a number of subsequent developments in storage formats. Both the digital audio tape (DAT) and, more significantly, the compact disc were developed in the 1980s. The CD officially debuted on 17 August 1982 (discussed in detail in case study section 6.1). The CD was an advanced technology at the time, and, apart from the new use of laser technology and digital audio, CD players themselves were also viewed as particularly advanced with respect to computing capacity, with the semiconductors utilised in CD players in the 1980s described as the most advanced ever used in a consumer product (see case study section 6.1), quickly becoming the recording industry's most lucrative product. (case study section 7.1, 9.4).

At the same time, compression techniques of digital audio were being explored, allowing for new broadcast products such as digital radio. Professor Karlheinz Brandenburg was a PhD student in the mid-1980s working on the compression of digital audio for the Digital Audio Broadcast project in Europe. After his PhD, Brandenburg worked with Jim Johnson at Bell Labs before returning to Europe to work with Leonardo Chagilioni of the newly formed Moving Pictures Expert Group (MPEG). MPEG was charged with the task of developing compressed video and audio standards for multimedia technology such as the CD-ROM. During this process, Brandenburg worked on the compression algorithm that became MPEG layer 3, with the format finished in 1992. After releasing the MP3 format to the public, Brandeberg remembers that, to begin with, nothing happened. For two years, apart from sporadic use as a tool for audio feeder links for video broadcast at the Winter Olympics, as well as being used for recordings of station announcements on trains and busses, there was little interest in the format.

If viewing the creation of portable digital music player as a product that relied on existing technologies, the above exploration reveals that in respect to one component- digital music and associated compression techniques- had a long trajectory of development that preceded the emergence of portable digital music players. This trajectory of digital music was not created explicitly for the purpose of portable digital music players, nor was it initiated after the concept of portable digital music players was known. Another component technology will also be explored below.,

6.3.3.2 PCs accumulate capacity to play digital music

Along with the development of digital music formats and compression, computing hardware also dramatically changed between 1970 and 1997, providing new capacity that previously wasn't possible. The difference in capacity is clear when comparing characteristics (size, weight, cost) of Kane Kramer's IXI player drawings from 1979 with the Listen Up Player, MPMan, and Diamond Rio of 1997 and 1998, reflecting the more general changing characteristics of computing during this time.

Computers began as military tools used for calculating firing tables with ENIAC in the 1950s, moving to becoming industrial machines with minicomputers costing $250,000, with the first notable commercial application, the SABRE reservation system, used by American Airlines. In the 1960s and 1970s, the minicomputer emerged as a multibillion-dollar category dominated by Digital Equipment Corp (this trajectory is described in detail in various case study sections).

At this time in the 1970s, the trend in the changing performance of computing was first noticed – the performance of computing components was improving as their price dramatically decreased. This concept was described in a number of theories, most notably as Moore's law, which focussed on the reliable performance improvement in transistor counts (discussed in case study section 4.5), along with other more informal recognition of this process, including that of Nelson (1974) in Figure 6.9.

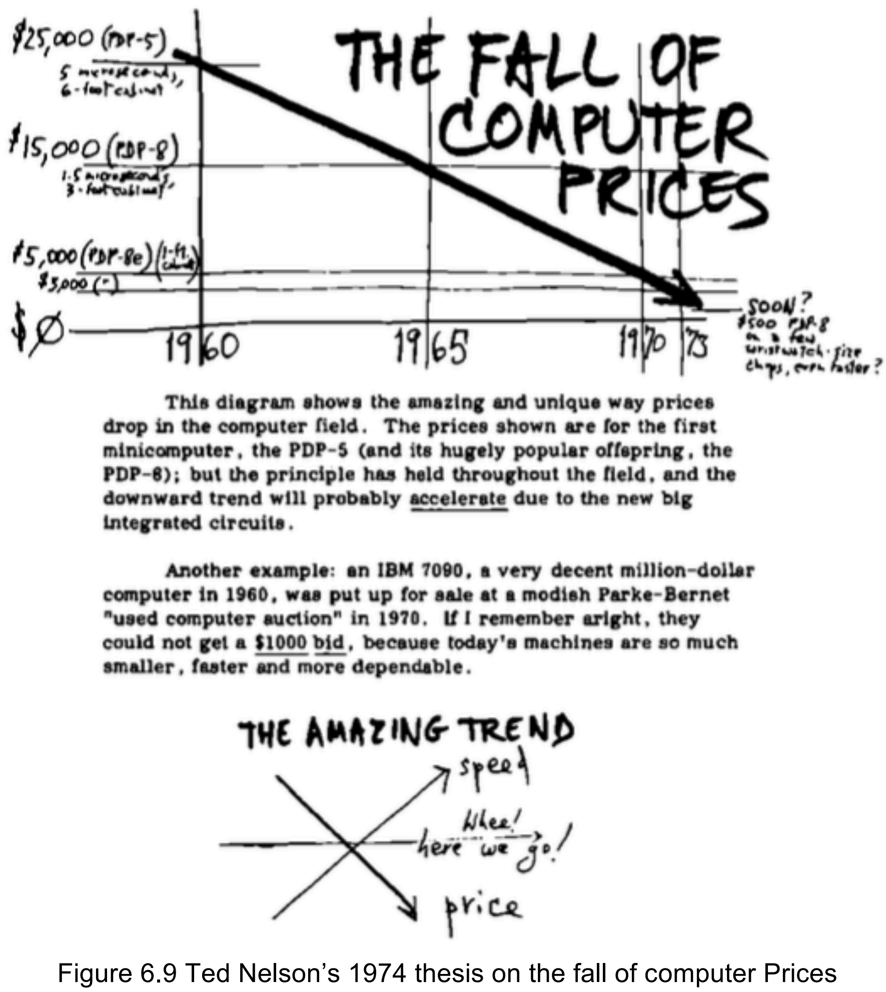


Figure 6.9 Ted Nelson's 1974 thesis on the fall of computer Prices

The increase in performance and decreasing price of mainframe and minicomputers not only made existing computer products and models more accessible for business, but the increasing performance soon enabled entirely new forms of computing, and in the early 1980s the personal computer market emerged. Hewlett-Packard, Apple, Tandy, and Commodore were small but quickly growing companies based on the increasing popularity of using a computer at home or in the office. In 1981, for example, Apple had grown over 200% from the previous year, with sales of $350 million (Libes 1983, p. 314). By 1995, this had continued to grow, and PCs had become standard school and office machines and were increasingly common at home.

6.3.3.3 PCs gain capacity to play recorded audio

Referencing this development in the context of digital music, prior to 1990, PCs could not play recorded audio. Whilst PCs could generate polyphonic beep tones with the use of 8-bit FM synthesis, it was only with the emergence of hardware sound cards that included analog-to-digital and digital-to-analog converters that made possible the playing of recorded music on a PC for the first time. Whilst these analog-to-digital converters had previously been sold as expensive recording equipment and products created by companies such as Sony, it was the computer component manufacturing industry that took this technology and created smaller versions that became components for computers. The earliest commercial success was Creative Labs's Sound Blaster. It was a sound card that offered both a FM synthesis chip (with 11 simultaneous voices), combined with the added functionality of an analog-to-digital converter, and a reciprocal digital-to-analog converter. The Soundblaster was sold as an after market component for PCs, that users could buy and install on their own home computers. For the first time, the presence of these converters enabled the computer to play recorded digital music, which was recognised as a major achievement in 1992: "In just eleven years, PC sound has gone from beeps and boops to CD-quality audio" (English, 1992).

Beyond the analog to digital converter, the performance of other PC components such as memory and processing performance were also initially below a functional capacity for digital music, and it took some time for this capacity both to emerge, and then to become widely available meaning even in the early 1990s, processing performance still was not quite powerful enough to make the PC a reliable music-listening tool. Professor Karlheinz Brandenburg identifies that it was not until 1994 that all components and capacity were available for the computer to become a reliable device:

> *It was only in 1994 that MP3, or at that time we called it MPEG audio layer 3, could be stored on a PC, but you first always needed special hardware to do the decoding. The first PCs fast enough to do real time decoding were 100 MHz 486 or the first Pentium devices … At that time, not all PCs had audio out yet and so if it had audio out, you could directly play MPEG audio layer 3 from that PC. In fact that was when the file ending MP3 got into the picture … we still have the email which internally announced that from now on we will use the file extension MP3 in all our software and for all our files, and that was*

> *on the 14th July 1995. (Professor K. Brandenburg, personal communication, May 27, 2013)*

Between 1993 and 1996 PC performance/price continued to demonstrate the improvement characterised by Nelson and Moore's law. PCs continued to get faster and cheaper, and the capacity to play music, which was an experimental and expensive capacity in 1994, increasingly became a standard characteristic of computers. By 1995, Pentium processors were standard in new and lower priced computers, and with this, the PC was now being advertised to mass market consumers as a "multimedia" machine. Intel released and promoted their Pentium MMX (MMX standing for multimedia) chips in this time, with a range of TV advertisements that centered upon advertising the PC as a music-listening machine.

At a similar time, PC drives with CD-replicating capacity began to fall in price. In 1995, after the release of the Creative Labs Digital Edge CD-R burner, a range of articles emerged describing the concept of CD-Rs, giving details about how the drives work, and when consumers could expect them to be available in PCs. The price of these drives dropped dramatically, and by 1997 the drives themselves began to be sold for under $400 for the first time, similarly becoming increasingly standard components of even basic model new PCs.

The internet also emerged in the 1990s as a consumer tool, drawing from its own list of precedent technologies and insights. It was early in the internet's consumer development that it was used for music, and one of the most prominent first websites to offer access to downloadable music was the IUMA.

In 1997, the availability of MP3, sound cards, the internet, and PC-processing capacity was followed by software such as Winamp that now offered new tools for listening and organising MP3 music on a PC. Winamp was a music library software which offered new ways to store MP3 files, search for music, and create playlists. With 20 million people connected to the internet in 1997, and "MP3" becoming the most popular search term on the internet in 1998, Winamp captured this early behaviour to become an early success story in digital music. Winamp was then followed by new software that added to this capacity, making it also easy to copy (rip, burn) CDs, and it was MusicMatch that became the best reviewed of this new library software.

The difficulty of lineage

All of these developments represent the context, the lifeworld, which existed prior and amidst the creation of the first portable music players. The description above is also incomplete. It focuses on only a few key component technologies that proved important specifically to digital music players – other components that could have been retraced include battery technology, LCD screen technology, flash memory, plastics, metals, electricity, and so on. And with this, the specific and unique trajectory of digital music players is difficult to identify – it appears a general availability of these technologies and wider things (science technique, ideas, processes, etc) at the time, where many of these things that had their own history, as a trajectory of specific development required before the new combination of portable digital music players were created. There are clear requirements for the audio formats, analog-to-digital converters, and even related technologies like the internet to exist *prior* to the creation of portable digital music players, but almost all of these technologies were not created *specifically for* the use of portable digital music players, and much of this development didn't appear to be working directly or clearly towards the iPod.

Significantly too the source of these technologies and their trajectories is varied. Some emerged from the consumer electronics industry, others from the computer industry, others from the recording industry, and others too from wider scientific endeavours such as Bell Labs and MPEG. There doesn't appear to be any clear path of development that one industry has over all others involved, and instead, portable digital music player technology emerged more generally from the available set of capacities at the time, which the concept of the lifeworld attempts to describe. That is to say, it was the availability of these technologies generally available in the lifeworld at the time that led to the creation of the portable digital music player, and not the other way around, where these technologies were created to be used in digital music players.

6.3.4 Marker 4: There are some tangible new performance characteristics of these component technologies which make the new technology possible.

Beyond the diverse amount of existing technologies the first portable digital music players utilised, the changing performance of these technologies also appears important. The emergence of portable digital music players relied on technologies that themselves had been incrementally improving for a long time and, importantly, had reached particular performance thresholds that allowed them to be utilised for the new combinations of portable digital music players.

Rather than viewing the creation of the first portable digital music players as one made of entirely unfamiliar and new technologies, instead, it appears that the changing capacity of existing technologies allowed for new combination, and this was the source of creation for portable digital music players. Table 6.3 below presents the changing characteristics of some of these key technologies as utilised in portable digital music players.

Table 6.3 Changing characteristics of some key PC technologies

Component	**Changing performance**
Analog-to-digital, digital-to-analog converters	Converters first emerged in the late 1960s and early 1970s as professional grade music studio tools utilised by the major labels as a superior technology to analog tape. By 1990, the converters themselves had decreased in size, allowing them to be added to PCs with the creation of the Sound Blaster, which resulted in the PC being able to replicate sound for the first time. With increasing size performance, by 1997 converters were small enough to be included in portable players.
Flash memory	The MPMan and the Diamond Rio were both released with 32 MB flash storage capacity. These devices retailed for between $200 and $295. Flash storage was not a new technology in 1997; however, what was new was the price of performance characteristics. Compared to the earlier NEC Silicon Audio prototype in 1995, the same 32 MB flash storage capacity was described to have a cost of $2,000. NEC engineers in 1994 acknowledged this to be outside of the range of what consumers would be prepared to pay and offered a prediction for when this would occur: “NEC predicts, however, that 90 minutes worth of memory card capacity will cost approximately $100 by the year 2000; playback-only cards will cost even less” (Normille, 1995, p. 48).
Internet	The internet was not a new technology by 1997 when the first portable music players emerged. However, the popularity of the internet had changed dramatically from 1.7 million users in 1993 to 20 million in 1997. This dramatically increased the demand for audio, and whist MP3 was created in 1991, it was not until 1997 and 1998 that consumer interest emerged: “A largely underground phenomenon in 1997, the controversial MP3 file-compression format burst from obscurity last year [1998]” (Reece, 1999b).

This highlights the role of trajectories of existing technologies in the establishment of new technology. In the case of the portable digital music player, the first players released to the public like the Diamond Rio and the MPMan appeared to be made possible by the changing dynamic performance in a range of pre-existing technologies, which enabled them to be used as a new combination.

6.3.5 Marker 5: The new technologies will emerge as adolescent with limited performance and will now compete against a parallel technology in a stronger state.

The final marker of the establishment lifeworld follows on from the points above. Just as the incremental improvement in existing technologies appeared important to offer establishment conditions for the new technology (as a combination), the technology also didn't emerge as fully formed, but instead its performance was also constrained by the state of performance in components at the time.

There is recognition in the literature that most innovations are relatively crude when they are first created (Abernathy & Utterback, 1978, p. 42; Clark, 1985, p. 238; Henderson & Clark, 1990, p. 14; Rosenberg, 1976), after which they are improved upon as their performance and range expands (Lipsey et al., 2005, p. 86). This was certainly the case with the release of the MPMan and the Diamond Rio. These players brought with them a sense of potential but soon also received polarised reviews from consumers. Some viewed the technologies as advanced; others described them as very frustrating new technologies, largely due to memory constraints (the flash memory size limited them to holding six to eight songs) and problems with software installation. A sample of consumer reviews for the MPMan on Amazon offered at the time are offered in Table 6.4 (see case study section 9.3 for more detailed reviews):

Table 6.4 Consumer reviews of the MPMan

"Okay, so I'm bitter. But after jumping through two hours' worth of hoops trying to configure my system, the MPMan F20 still refuses to be recognized by the software it came with. Seems like poor design. I'm giving it an average star rating until their tech support gets back to me – after that, even if it works there's no way it deserves a 5. Too much frustration."
"I purchased The Eiger F20 about a month ago and I love it. The best thing about it is the unlimited amount of music that you can get online for free. It is smaller than a CD player and you don't have to buy CDs that have one song you like. If you listen to music a lot I definitely recommend getting this instead of buying new CDs all the time. It is a lot better than a RIO since you can swap out the Smartmedia cards. The only thing that it lacks is an equalizer (like the RIO) and an LCD screen that you can program to include the name of the track and the artist. Also, if you're going to buy this, buy some new headphones. Earbuds are fine for jogging and stuff, but if you want good sound quality get some good headphones. Overall I love this product."
"Don't waste your money on this product. It is a real piece of junk. I can't get mine installed despite repeated attempts. The documentation provided with the product is a joke. It is literally a photocopied four page piece of paper. I have called the support number for a week straight and never gotten a live person. Every time they email me in response to my inquiry they send the same automatic response message. Lastly the software provided is horrible. It is a bunch of clippings from 3rd party

web sites. I obviously can't tell you how this thing sounds since I've never gotten it working. Please save yourself the hassle – stay away from this product. Eiger Labs doesn't care about servicing its customers."

These limitations and frustrations were not isolated to portable digital music players but also were found in technologies of digital music more generally. The technologies that later proved critical to dramatic innovation didn't yet have the capacity and characteristic required to enable products such as the iPod, iTunes, and the iTunes Music Store. Table 6.5 presents a number of references to this:

Table 6.5 Technologies critical to dramatic digital music innovation

Component	**Changing performance**
Downloading music in 1995	Jeff Patterson, pioneering co-founder of the IUMA (one of the first online source for downloadable music), describes the complexity of downloading music over the internet in 1995: *So yeah we bought this MP2 encoder and MP2 player, and I think it was like a hundred bucks for the software to buy, and the player was freely distributable, so we could do that encoding, but not many people had the player and the MP2 codec wasn't built into any other player at the time, so in order to listen to it, you actually had to download this player – a Windows machines couldn't just play it. So that was definitely a hurdle. … And the problem too was that still even with the compression ratios we got it still took – you know, I had a 14.4 modem – so it took well over an hour to upload the song, and I don't know if you've ever been on Usenet at all, so it's a set of text posts, so to upload a binary file you have to do something called UUencoding, where it transforms the binary file into a text format, and then it splits it into parts because there's a maximum file size for each post, so [to download and listen to the demo] you had to download 26 text posts, you had to stitch them in a text editor, and then you had to run it through an encoder. Then you could you play it if you installed the player, so it was pretty complicated … But eventually MP2 caught on, and then MP3 caught on. (Jeff Patterson, personal communication June 26, 2013*). Due to the complexity, Patterson describes the first users at the time as, "tech savvy people with a high bandwidth connection, so people at universities were mostly it. … It was basically music-loving computer

Component	**Changing performance**
	science students." *(Jeff Patterson, personal communication June 26, 2013).*
PC performance	Professor Karl Brandenburg creator of the MP3, reflects on the state of technologies in this time: *"At that time [1995], the complexity was still too high for widespread application for distribution and so on. It was really only when every PC was fast enough on one hand and did have the soundcard built in on the other hand that this really took off. And that again technically was the case in 1995, but really the avalanche was going in 1997 in some sense." (Professor K. Brandenburg, personal communication, May 27, 2013)*
Download speeds	In 1997–2000, internet download speeds were frustrating. For example, using a common 56K modem, it could take more than 2 hrs to download an album of songs (Gillen, 2000b). Perhaps this is also what accounted for the popularity of MP3 in 1997 and 1998 – it was a compression standard that reduced file sizes, increasing efficiency of downloads relative to sound quality. Long download times also made CD burning a much more popular consumer behaviour in 1997 and early 1998.
Hard drive capacity	Hard drive performance, which later would also prove critical to the emergence of the iPod, was comparably limited for music-specific devices in 1997. Specifically, in the 12 April 1997 edition of *Billboard* there was an article that described the accelerating trend of radio stations implementing hard drive computer music systems to replace or supplement their CD collections. The article, first offering reflection on the growing awareness of digital music, said, "Digital continues to be an industry buzzword (to the point that it has crossed into the mainstream vernacular)". Traiman (1997) describes the increasing popularity of hard drive systems at radio stations worldwide, with an estimated 1,500 radio stations having migrated their CD systems to hard drive libraries. 1997 is described in the article as an important threshold year for these systems. Whilst they were available from the early 1990s (originally as 1–2 GB systems), by 1997 a range of entrepreneurial companies (e.g., Broadcast Electronics, Enco Systems, RCS, and Computer Concepts) were selling 9 GB hard drive systems. The market leader was Broadcast Electronics, capturing 25%–30% market share, with their 9 GB Audiovault system retailing for $20,000 (Traiman, 1997). Despite the extreme expense of these systems, particularly in comparison to later

Component	Changing performance
	portable players, even at these prices the systems were viewed as a cost-saving tool for radio stations.

As a result of this adolescent performance, there was contested assessment of the value and potential of the technology. It wasn't clear that portable digital music players were the obvious avenue of advance, nor that digital music downloading more generally would replace CDs. This appears common to most successful radical technology (Christensen, 1997). History appears replete with dismissive assessments of technologies based on early limitation, despite these technologies later proving to be powerful innovation. The turbine engine, for example, was initially dismissed by the U.S. government due to its preliminary inefficiencies: "There does not appear to be, at present, any prospect whatever that jet propulsion of the sort here considered will ever be of practical value, even for military purposes" (Buckingham, 1922, p. 85). An internal memo at Western Union assessed the telephone similarly: "This telephone has too many shortcomings to be seriously considered as a means of communication. The device is inherently of no value to us" (Western Union internal memo, 1876). These assessments were factual at the time, but incremental improvement in the technological components with time revealed new performance that proved these assessments wrong.

In the case of the portable digital music player, this resulted in considerable uncertainty regarding the potential of the technology. Portable digital music players, particularly flash-based players, represented but one of many alternative avenues of advance. And at the time, for a recording industry that was achieving its highest revenue levels of any time in its history, the CD remained the dominant alternative. It wasn't yet clear or obvious that downloads and portable digital music players were the correct strategies to pursue. The uncertainty is also captured in choices from the consumer electronics industry at the time– Sony, who had a history as *the* pioneering company of digital music, responsible for the Walkman and the CD, decided against entering the portable digital music player market initially. The same year as the MPMan and Diamond Rio were released, Sony initiated their largest and most expensive advertising campaign to promote their MiniDisc format, suggesting that the future remained contestable, and it wasn't yet obvious what impact the portable digital music player was to have.

6.3.6 **Establishment lifeworld summary**

This concludes discussion of the establishment lifeworld. Summarising this lifeworld, there appear to be particular conditions of accumulation in availability and performance of existing technologies that led to the creation of the first portable digital music players. These devices are combinations of component technologies, and these component technologies themselves had preceding trajectories, some developing for more than 20 years before the release of the first players. In analysing what made the portable digital music players possible in 1997 and 1998 rather than earlier, it is the incremental improvement in these technologies that reach particular performance thresholds that made possible these players that at other times were not possible. The establishment created novelty, and this novelty emerged as uncertain in respect to future value. The next lifeworld, the development lifeworld, is where a significant amount of work emerges to improve and configure this initial technology.

6.4 Development lifeworld

The early technologies of the establishment lifeworld do not lead to significant innovation immediately. The third lifeworld, called here the development lifeworld, describes the most dramatic design work of the technology and appears at an important time between the emergence of the technology and the achievement of powerful innovation. In this time, the domain becomes more clearly established, and whilst the technology is initiated as crude, adolescent, and uncertain, it improves through processes marked collectively as development in this lifeworld.

This development lifeworld between 1999 and 2001 was the most dramatic time of advance for portable digital music players. There was a large volume of market entry from companies offering new products, all of whom were experimenting with new players. Along with this, more broadly in digital music there were a number of dramatic events and developments that offered a wider context that also influenced development of digital music players.

There are three key characteristics to describe the development lifeworld in the model chapter. First, there is expected to be a recognisable increase in entrepreneurs offering new products based around the new technology (Klepper, 1996). These products initiate a process of variation and selection, where the selection environment (Nelson & Winter, 1982) of the wider lifeworld reveals the constraints and limitations of the technology over a number of socioeconomic influences. Second, the technology faces significant competition in this lifeworld. It has now emerged as a distinct technology but remains one of many parallel alternatives, with recognition that there will be pre-existing alternative technologies with stronger performance and alignment that it now must compete with. With the problems of the technology revealed by trial and error in this lifeworld, the capacity of the technology to achieve innovation fluctuates and remains uncertain. Finally, accumulation in capacity of existing technologies in the lifeworld discussed in the establishment lifeworld continues, and whilst trial and error reveals problems and limitations, ongoing accumulation offers new forms of technology, with greater levels of performance that weren't previously available. This has the effect of making assessments of the technology difficult and often being quickly proved erroneous on account of how quickly the characteristics and limits of the technology are changing quickly.

To describe and summarise the detail and activity in this lifeworld, a range of markers are offered. These are presented in Table 6.6 and will be the focus of discussion in the coming section.

Table 6.6 Development lifeworld markers

Marker 1	There is a dramatic number of new competitors, from a variety of industries, offering new products around the new technology.
Marker 2	These new products initiate variation and selection processes, which reveal problems and limitations with the new technology across socioeconomic criteria of the lifeworld.
Marker 3	Accumulation in capacity of the lifeworld continues, and this creates further opportunities for exaptation and combination, with components of greater capacity becoming available.

6.4.1 Marker 1: There is a dramatic number of new competitors, from a variety of industries, offering new products around the new technology.

1999 to 2001 was a dramatic time for the portable digital music player market. There emerged a large number of new entrants to the market, offering a variety of new products that built upon initial designs offered by the MPMan and the Diamond Rio. These new players were released from a variety of companies from consumer electronics, computer component, and PC industries, and included a variety of prominent high profile brands (such as JVC, Toshiba, Samsung, RCA, and Compaq) as well as a number of smaller entrepreneurial efforts (i-Jam, Sensory Science, and Creative) (see Figure 6.19).

Figure 6.10 Large variety of flash memory portable players

Whilst there were differences in design and technology choice (such as screen size and battery choice), most of these players were based around the same technological components as the MPMan and the Diamond Rio, most notably with all players of this style using flash storage as the key memory component.

During this time, there was widespread acknowledgement and consensus that flash storage was the future product of the industry, reliant in part upon the expected and demonstrated trajectory of improvement in the technology. Whilst the MPMan and Rio Diamond were both released with 32 MB flash storage, by mid-2000, 64 MB memory players became increasing standard, with a number of others offering expanded memory, such as the Soul player by AVC Technologies, which was the first player to announce 128 MB flash memory (see case study section 9.3, 10.4).

The large volume of players released in this time not only explored technical features but also appeared to search for particular consumer niches. Players were designed and marketed for uses such as sports (Nike PSA player), fashion (Panasonic eWear, Casio Wrist Audio), industrial design and luxury (Bang and Olufsen BeoSound), and use in cars (Digiset Duo Casette MP3 player). A sample of these players is offered in Figure 6.11.

Figure 6.11 Alternative design portable digital music players

The increasing number of new entrants with a constant stream of new product releases brought with it increasing attention to the portable digital music player category as a whole. Consistent with the importance of selection feedback noted by Simon (1962, p. 473), there emerged particular news websites that chronicled developments and new releases. These websites offered reviews, interviews, and opinion on emerging developments. Websites such as mp3newswire.net, webnoize.com, and Wired's Mp3 Rocks the Web are three prominent digital music news websites that emerged at this time. Digital distribution news also became a focus at *Billboard*, the long-standing recording industry journal. Some of these sources were consumer facing, such as mp3newswire.net, which had a focus on reviews of new players for consumers. Others were hybrids, such as Mp3 Rocks the Web and Webnoize, which offered both industry-level analysis of trends (with purchasable reports) and information for consumers. *Billboard* remained largely a specific recording industry publication.

Along with these new news sources, there were also a large amount of conferences dedicated to digital music in this time. The Mp3.com Summit was a yearly conference, Webnoize ran large-scale yearly conferences, and Harvard had a conference called Signal and Noise, among many others. The mix of conference events and news sources updated with new information daily or even hourly at times, played a critical role offering valuable feedback to entrepreneurs engaged in the marketplace during this time. The emergence of these "selection feedback" news sources and conference events appear a good marker of the development lifeworld, highlighting the importance of gaining new information about feedback as a critical source of competitive advantage at this time.

6.4.1.2 Multiple developments

Along with the increase in the amount of new portable digital music players, much like the component technologies that emerged from a wider context in the previous lifeworld, during this time there were a number of dramatic concurrent developments more generally in digital music. These relate to PC-based music tools such as library software, CD ripping and burning on PCs, MP3 search on the internet, and then Napster. Amidst these events, there was also significant major label experimentation, including the Madison Project partnership with IBM, the large-scale standard setting attempt in the SDMI, and the release of MusicNet and PressPlay, two online music services controlled by the major labels. These developments did not occur specifically on behalf of the development of portable digital music players, but they are related, and represent a general context, the lifeworld of the time, which had a profound impact on the subsequent direction of portable digital music players, with the later emergence of the iPod responding to many of the issues emerging in this time to provide one of the first integrated solutions across portable player and digital music library software. A number of the important developments that occurred during this lifeworld provided the direct context for the later emergence of the iPod, and these important precedents will be described separately below.

6.4.1.3 Music library software

Following on from the recognition of the PC as a multimedia tool that occurred between 1992 and 1996, between 1997 and 2001 this performance became widely distributed. CD Read Write drives (enabling CD ripping and burning) became increasingly standard components of PCs (see case study section 9.2.2, 10.1.1), as levels of internet connectivity continued to reach pervasive levels (case study section 9.1, 10.1). In the U.S., as of September 2001, the Department of Commerce Census Bureau estimated that 60.2 million U.S. households (or 56.6%) owned a computer, and of these 80% were connected to the internet (U.S. Department of Commerce, 2011; see also Crandall, Jackson & Singer, 2003, p. 5), with high speed internet most notably available at many U.S. universities.

Using a PC for digital music became popular. Winamp, which was the leading MP3 library software in 1997 (see case study section 8.2.3) had increasingly been superseded by newer software aimed at offering music library capacity integrated with CD burning and ripping capacity (see case study 10.1.2). Winamp was soon eclipsed by newer products such as Windows Media Player and Real Audio's RealJukebox Plus, along with other specific burning software such as Roxio Toast, which were all available at this time. But it was another product, MusicMatch, that offered a wider amount of product features, recognised as the first fully "integrated" solution that in a single software made it easy to import CDs, manage/listen to a music library on a PC, make playlists, and export music by burning to disc or to an external MP3 player (Business Wire, 2001). MusicMatch was recognised as the superior software of the time: "[it] does what you want, with the least hassle and the best results" (Mossberg, 17 July 2001; see case study section 10.1.2).

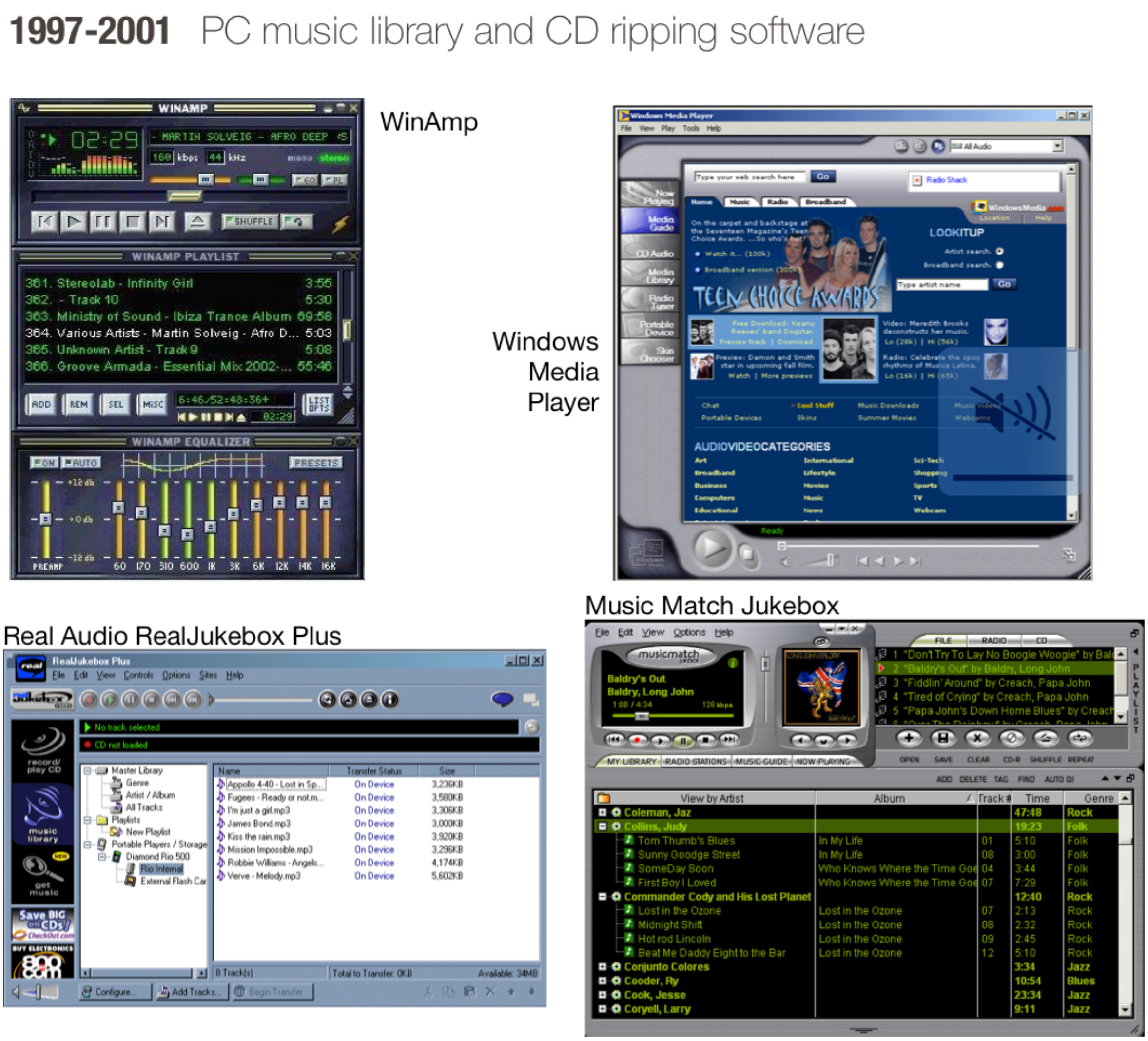


Figure 6.12 PC music library and CD ripping software

6.4.1.4 Online MP3 search tools

Along with these developments in music library software, there were a range of internet-based tools that made it easy for internet users to search for and find MP3 files. At this time, MP3 rapidly became dramatically popular as a consumer format. By October 1999 it had become the most searched term on the internet, as downloading music became a popular use case for internet-connected home and university PCs (Jones & Sul, 14 October 1999).

There were a range of online websites and software tools that emerged to help users find MP3 files online. The pioneering work of the IUMA, which avoided offering major label content on account of copyright issues, was quickly surpassed by a range of new products. Entrepreneur Michael Robertson recognised that “MP3” was becoming a popular search term on the internet and quickly purchased mp3.com for $1,000. Robertson initially made mp3.com an information website for the music format but quickly expanded to offer independent music. Mp3.com became a leading website for music from independent artists, and Robertson a prominent advocate for online music. The company also listed on the stock exchange, riding the wave of the dot-com boom and making Robertson a billionaire briefly. Mp3.com then pushed the limits of intellectual property to gain access to major label content, offering new products such as an online locker service using their "beam it" technology. It resulted in a lawsuit from the major labels for copyright infringement which mp3.com lost, after which, in 2001, Robertson sold mp3.com to major label Universal Vivendi.

With the popularity of CD burning and ripping and PC-based music library tools, there was a growing amount of major label songs that users had converted to MP3 and were storing on their PCs. With the rise of the internet, the next step was the sharing of these files, leading to a dramatic piracy problem for the major labels. There was small-scale activity and sharing of pirated material on Internet Relay Chat channels such as the popular "Warez" channel, which offered users access to pirated material. It led to one of the first prominent court cases for copyright infringement for illegal downloading with United States v. Jeff Levy (case study section 9.2.4). Levy was a student at the University of Oregon, where he had access to broadband, and, utilising this, started sharing his music and software collection, as well as downloading content from other users in the ISO Traders Channel:

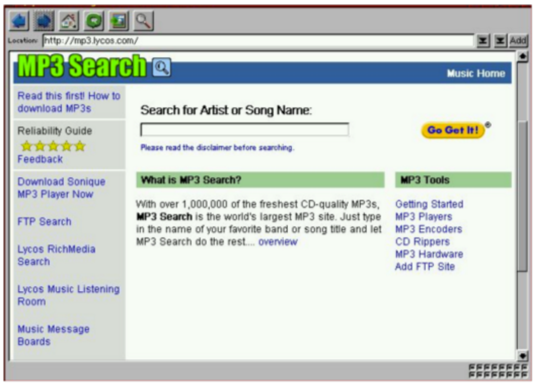
> *I'm like, oh, this is something I can do because I have a CD burner, and I have a really fast connection to where I can download a 600MB image file in 10, 15 minutes … but what was interesting in a way, too, was that you no longer required any sort of knowledge of writing code or changing the packing [to] pirate the software.. … You didn't necessarily have to do that anymore. Because you have the CD burner to do that. (Jeff Levy, personal communication July 9, 2013)*

Whilst his university had first reported Levy to the government suspecting he was the organiser of an advanced online piracy ring due to the volume of downloads and uploads (estimated at 10 GB a day), it was revealed in the court case he didn't have a coordinating role on Warez or ISO Traders – more simply he was just a university student that had access to broadband and was using its capacity to share content. He was found guilty of copyright infringement and sentenced with a fine and a ban on internet connectivity.

Along with this, a new raft of consumer-facing websites made it possible to search the internet for MP3 files. Specifically, mp3.lycos.com was a leading search engine where users could search the internet for a particular song. Sean Fanning, creator of Napster, suggests that in 1998 and early 1999 he and university friends were using mp3.lycos but had found the service problematic. Fanning described that the service would often return search results that included broken links or links that would time out (Aydar, 2005). In response, Fanning conceived of a peer-to-peer software architecture that he subsequently developed into Napster. Fanning spent a few months coding a prototype himself (Beato, 2000). Napster CEO Hank Barry describes the context that led to Napster's creation:

> *So you are in a dorm where everybody has broadband access, and you are in a mix where you've got people with big hard drives, MP3s – by the way, there's no cable TV in the dorms, so you don't have any cable TV, but you do have broadband access. So what are you going to do for fun? What are you going to do? And you don't have any money, alright, you can't buy any records. So in this mix, you have a powerful kind of soup. … Bored, no money, access to broadband, access to these MP3s. … you also had MP3 players around, so people listening to them [mp3s], but basically to get them you have to take somebody's hard drive. You have to physically walk it over. (H. Barry, personal communication, July 10, 2013).*

1997-2001 Internet based mp3 search tools

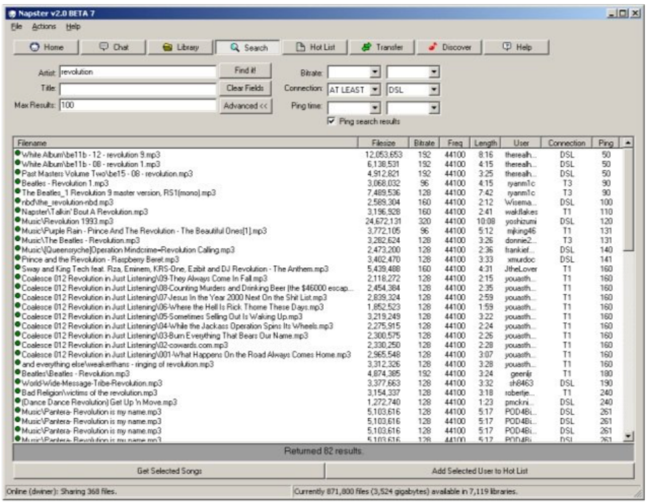


mp3.lycos search engine (1997-1998)

Napster (1999-2001)

(Napster website)

http://web.archive.org/web/20000304124523/http://napster.com/whatisnapster.html



Napster (software)

https://www.shopify.com/enterprise/91808198-how-broadband-has-changed-the-world-part-2-napster-myspace-and-the-dawn-of-web-2-0

Figure 6.13 Internet based mp3 search tools

Napster was launched in June 1999 and soon became a dramatic consumer and cultural phenomenon (Napster is discussed in detail in the case study section 9.6). Its adoption was sheer in scale and speed. The effectiveness of the peer-to-peer software design of Napster gave users free reliable access to almost the entire catalogue of music. RIAA CEO Cary Sherman discusses the popularity of Napster:

> *[Napster] just unleashed a consumer free-for-all with respect to everybody having whatever music they wanted. A lot of people were collecting music just for the sake of collecting it – a lot of music that they downloaded, they never even listened to. I mean, it was a frenzy. It really was. (C. Sherman, personal communication June 27, 2013).*

On 7 December 1999, the RIAA, representing 18 record labels, including all the major labels, sued Napster for contributory and vicarious copyright infringement (Clark, 1999). The original decision from Judge Patel was viewed as a clear win for the RIAA: “Napster had been legally eviscerated” (Ante, 2000). There were appeals, but ultimately the court case led to Napster having to filter out all copyrighted material from search responses, which proved difficult. On 1 July 2001 Napster shut down its service, after losing 65%–70% of its users in the four months between February and June 2000 (Stone, 2001). The growth in the size of Napster is summarised in the previous analysis chapter, and Napster is also covered in detail in the case study.

Following Napster, a wave of second-generation peer-to-peer products emerged, including Limewire, Morpheus, Scour, Red Swoosh, and most notably Kazaa. Kazaa quickly filled the void of Napster, and eclipsed it in user numbers both on account of the large migration of Napster users as well as increasingly mainstream familiarity with peer-to-peer products (Kazaa and other second-generation peer-to-peer services, which are discussed in detail in case study section 10.1.3). This too led to lawsuits against these second-generation services post-2001.

These products represent a clear shift in the capacity of digital music. Drawing on the increasing widespread access and familiarity with PC technologies and the internet, Napster particularly revealed the internet’s capacity as a tool for digital music distribution that was profound and shocking, with Napster itself transcending description as a product to become instead a major source of cultural intrigue and inflection.

Variation and selection feedback

Variation and selection increased as a result of the large volume of portable digital music players released as well events in digital music more generally. Reviews of these products, consumer feedback, experimentation by manufacturers, and critique and discussion from the available news and conference sources made expectations about better designs clearer, as well as exposed a range of reverse salients (Hughes, 1983) or problems with these new players. These problems emerged not only as technical challenges, but also problems at a range of socio-economic criteria. The model chapter discussed four alternative types of socioeconomic variation and feedback (component, consumer, complementary, and culture) and the activity and problems that emerged on these four levels will be discussed individually below.

6.4.1.5 Component level variation and feedback

The model chapter described that in the early stages of a technology there is likely to be experimentation with core component layout and configuration of the technology. In the early stages of the automobile industry, for example, cars were offered with gasoline, electric, and steam engines, as well as wood and aluminium bodies (Abernathy & Utterback, 1978; Henderson & Clark, 1990, p 14).

There was experimentation with component design in this stage of portable music player development. As mentioned in the first marker, the technical component layout of the Diamond Rio and the MPMan became a popular base for other products, and there was a large variety of similar players based around 32–64 MB flash memory. Flash memory was viewed as the central technology for the future direction of portable players at this time, with enthusiasm emerging from consumer electronics, the recording industry and computer component manufacturers alike (see case study section 10.4). However, with the cost/capacity of flash memory still limited, at this time “memory format” components also became an important source of experimentation.

Whilst there was acknowledgement that the trajectory of flash would eventually offer players better performance from industry as well as consumers, there emerged alternative memory formats that attempted to address the short term cost/performance problems of flash memory. Specifically, the “PocketZip disc” (originally named “Clik! Disc”) was released by Iomega, with discs that were larger than flash in terms of physical size but offered a storage capacity of 40 MB and retailed for $10 (Menta, 2000a, 2000b). This offered a significant cost advantage over flash at the time (see case study section 9.4). These discs were used for some players, but as the cost of flash improved, these players lost their advantage. The PocketZip format failed three years after its debut.

During this time of memory component experimentation, there emerged an entirely different alternative to flash and the PocketZip that offered dramatically different storage capacity, launching a category of portable players called “jukebox players”. These will be discussed below.

6.4.1.5.1 Jukebox players

Magnetic hard disk drives were an important component of PCs and laptops, which were both significantly growing product categories in 1998 and 1999. With this, there was continual push for incremental improvement in the performance of these PC and laptop disk drives by component manufacturers. As a result of this incremental improvement (marked by individual insights, such as IBM researcher Stuart Parkin and colleagues’ creation of the “spin drive” and “spintronics”, which gave the capability to alter the magnetic state of materials at the atomic level; Markoff 2007), by 1998 it became possible to create significantly smaller physically sized hard drives that retained a relatively high storage capacity. In 1998 and 1999, a range of manufacturers, including Compaq, IBM, and Toshiba were working on creating these smaller drives. The first to market was Compaq, who initialised this new category of small hard drives with what it referred to as simply a “2.5 inch laptop hard disk” (Camerani, 2012, p. 63). IBM soon followed with their own “Microdrive”, which was a hard drive that had much smaller physical dimensions relative to the previous PC and laptop hard drives (see case study section 9.3, 10.4).

Soon the availability of these small drives led to new developments in portable digital music players. Utilising Compaq’s 2.5 inch laptop hard disk, engineers at Compaq’s Systems Research Centre created a dedicated music player called the Personal Jukebox 100 (PJB-100; Wired News, 1999). The player utilised other components that were common to PCs and other MP3 players available in the market, such as the LCD screen, Ethernet interface, and rechargeable lithium battery (Rhode Island Computer Museum, 2014), but rather than use flash memory, Compaq used its own unique 4.86 GB hard drive, dramatically changing what was possible compared to flash memory. Whilst the PJB-100 was more bulky in physical size compared to flash memory players, where flash memory players could store a maximum of eight to 15 songs, using the Compaq hard drive, the PJB-100 could hold 1,000 songs.

This was a dramatic advance, and by utilising the laptop hard drive, the research team at Compaq had created a new form of portable digital music player that was soon viewed as a distinct category marked “jukebox players”, as other competitors offered similar designs. The advertising of the PJB-100 zeroed in on the distinct value it offered users, calling it the most powerful MP3/audio CD player on earth, promoting that you could carry your CD collection in your pocket, (very similar to Jobs’ future tagline for the iPod of “Your entire music library fits in your pocket”). Figures 6.14, 6.15 and 6.16 present the player as well as the initial marketing for the device.

Figure 6.14 Compaq PJB-100, the pioneering hard drive digital music player

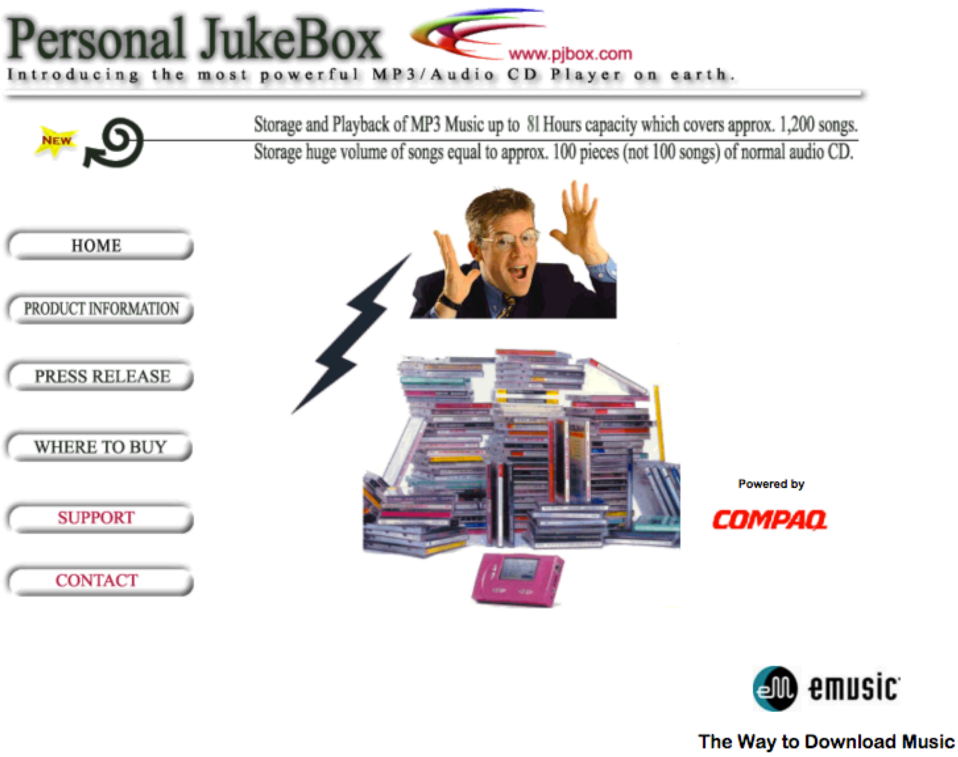


Figure 6.15 PJB-100 website and advertising

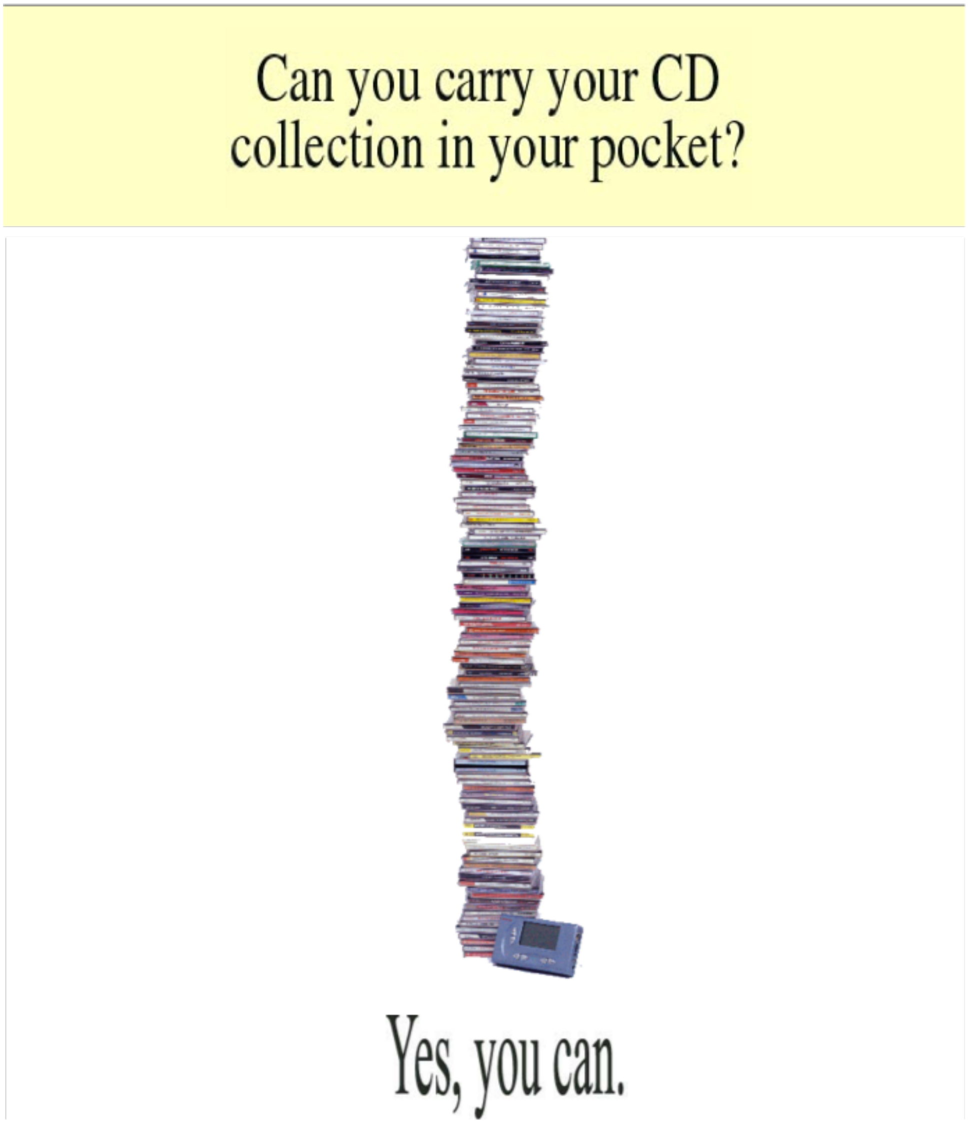


Figure 6.16 PJB-100 website and advertising

With the PJB-100 emerging from a specific research team in Compaq (with the team itself being a core group of previous Digital Equipment Corp. employees that transferred with Compaq's previous acquisition of DEC), the higher leadership team at Compaq did not pursue the portable player. Instead after the prototype stage, Compaq stopped development on the device and withdrew from the category, focusing on the personal digital assistant category instead. Compaq then sold the PJB-100 design to an independent company called Remote Solutions, who released the same technology to the public as the Remote Solutions Personal Jukebox. When released as the Remote Solutions Personal Jukebox, the player was recognised as a landmark development. Mp3newswire founder Richard Menta, for, example described it as a breakthrough:

> Remote Solutions Personal Jukebox is a milestone product. By that we mean any product whose breakthrough innovations are so significant, they influence the future course of its industry (Menta, 2000a).

Soon after, a range of competition from companies such as Archos and Creative emerged that similarly utilised small PC hard drives to offer players the capacity to store over 1,000 songs (see Figure 6.17). This category of players soon came to be recognised as the jukebox category (see case study section 9.4).

Figure 6.17 PC hard drive based Jukebox players

These portable jukebox-style devices were well received on account of their storage capacity, but limitations were soon described. Reviews described the library capacity as fantastic but lamented issues with size, weight and portability, limited battery life, often complicated menus (Creative being the exception), and slow transfer speeds from PCs (see case study section 9.4).

With both jukebox players, along with the much smaller flash memory players, being sold to the market, these two categories were viewed as related but ultimately independent categories, with the smaller flash-based players having the majority of manufacturer focus and being the more significant category on account of the expected fall in the price of flash memory in the years to come (see case study section 10.4). These two categories represent important trial and error at the component level during this time.

6.4.1.6 Consumer feedback

The second level or type of variation and selection feedback level was that from consumers. As noted in the model chapter, consumers play a central role in the development and configuration of technology. The technology is not delivered ready-made with meaning articulated prior to consumer use (Tuomi, 2002, p. 9), but instead consumers actively define and shape its meaning (Fischer, 1992, pp. 84–85). The role of consumers has been recognised as so central to the development of technology that their role has been acknowledged to be the most important: “The single measure which discriminated most clearly between success and failure was ‘user needs understood’” (Freeman & Soete, 1997, location 4501).

Consumers were important during the development of portable music players through this time. Most notably, consumer reviews of existing players highlighted the problems with flash memory and usability, as well as the relationship with software.

Despite the industry enthusiasm for flash memory, from a consumer perspective, flash memory players remained frustrating. The cost/capacity of flash storage at the time limited these devices to being able to play six to 15 songs only, and the cost of increasing this capacity by an extra six to 12 songs remained very restrictive (see case study section 8.3). Amazon customer reviews from this time acknowledge the memory constraints and cost of flash as a significant frustration with these players. See case study section 8.3 for an extended range of reviews, but a small section is offered in Table 6.7:

Table 6.7 Flash memory portable player consumer reviews

Reviewer: Matthew Date of review: 26 November 1999 Player reviewed: Diamond Rio	The Rio PMP300 is a great portable system if you have access to your own computer. Some advantages are that it's very small, very light, it doesn't skip, it only takes 1 battery which runs for at least 10 hrs, and the music can be free on the internet. You can also take tracks right off your favorite CDs. The 1 problem that I have with it is that it only holds 32 MB which is about 7 or 8 CD quality songs. It could hold more if you don't mind radio quality. If you want to get more memory on this thing it's not cheap. You can double your memory from 32MB to 64MB for about $100.
Reviewer: Nick Paul Date of review: 12 July 1999 Player reviewed: Diamond Rio	It plays perfectly, and I have no complaints with the performance. But if you are going to take this with you as a truly “portable” unit you are going to be stuck with only 30 minutes of storage for cd quality music. Maybe that's not a problem for you, but personally I need more of a variety of music when I take this on a trip. And the extra 32-meg flash memory cards cost $100!!
Reviewer: E.K Date of review: 2 July 2000 Player reviewed: Creative Nomad	I'm not going to get all technical now, except the fact that NOMAD can support other future formats like WMA, and most of the other top-selling ones do not. OKay...NOMAD has a limited memory of 64MB. Most of the others do too. Yeah, there are some that hold 96MB now, but who knows...wait a few years and it'll probably be a couple Gigabytes...that is, if future formats of music files do not make mp3s obsolete.

Flash was a prominent technology, to the extent that major consumer electronics companies like Toshiba were prominent advocates for it, and even the record labels such as Universal, EMI, and BMG all invested in, released, and promoted their own flash card album format called Dataplay. There was a clear difference between consumer experience of these devices at the time, and the expectations of the format from industry.

Further exploring the role of consumers in the process of variation and selection, the rise of file sharing is another powerful activity through this time. The embrace of first MP3 and then Napster was a significant consumer-driven behaviour that had a major influence on the development that occurred. The rapid consumer embrace of Napster particularly changed expectations and the timeframe for the development of digital music distribution. This consumer behaviour shifted the negotiating conditions for both the labels as well as the young entrepreneurial companies, brought political pressure on the labels, and increased the rate of experimentation in digital music distribution.

Consumer embrace of Napster also changed the expectations regarding usability. In the final stages of Napster, there was a clearer expectation that for software to compete with Napster it had to offer a similar friendly usability experience (see case study 10.3.3, 11.1), and the importance of consumers embracing MP3 was a major driver of industry decisions regarding the required usability of services, with an accumulating understanding that to compete with Napster, paid products had to do so on usability.

Whilst there were many avenues explored through this time with new products, the response from consumers to these products was a powerful catalyst for further advance. It was consumers who had a strong, albeit not absolute, authority on the direction of advance, and products that failed to achieve consumer response were soon discarded. Products that did initiate strong consumer response, such as Napster, appeared to be embraced as offering feedback for further development.

6.4.1.7 Complementary alignment and feedback

The third type of variation identified through this lifeworld was at the level of complementarities. The model chapter described that the value of the technology does not emerge in creation, but its value is dependent upon a range of complementary technologies, suppliers, and distribution channels in order to function effectively and achieve innovation (Rosenberg, 1983, p. 59). The automobile, for example, as Unruh (2000, p. 822) notes, was dependent upon industry coordination of complementarities such as petroleum, glass, rubber, and steel, as well as the coordination of industries (and governments) related to availability and production of roads – asphalt, concrete, and steel industries. For any particular technology, the process of emergence and configuration of these complementarities is difficult, but one that is central to the innovative performance of a particular technology (Geels, 2002, p. 1270).

This issue is one of complexity and importance for portable digital music players. Complementarities represented a critical determinant of performance in digital music. The major record labels, who owned and controlled approximately 80% of the catalogue of recorded music by this time, were a critical determinant, and the labels themselves were heavily aligned with the CD format (and associated partnerships with manufacturers and retailers of both CDs and CD players). This made the transition to portable digital music players difficult for both the industry and for new digital entrepreneurs dependent upon the industry for legitimacy.

The major labels had a strong existing relationship with the consumer electronics industry, and whilst many consumer electronics companies were engaged in the portable digital music player market, these companies were not ultimately the source of innovation. Instead the major companies that created innovation emerged from new software entrepreneurs, PC component companies (Creative, Diamond, Sandisk), and PC companies (most notably with Apple).

During this development there was a a significant adjustment to relationships. The recording industry at large had to initialise a separation with retailers, adjust the relationship with consumer electronics companies, and establish new relationships with IT companies. This was a complicated task, and one that was not obvious to begin with either, where instead the nature of required relationships became clearer on account of increasing precedent due to variation and selection. A number of perspectives of key suppliers and industries who confronted the shift caused by digital technologies will be discussed below.

6.4.1.7.1 Major labels

It was a very active time for the major labels, and from a very early stage the major labels engaged in experimentation regarding digital music distribution. Prior to Napster the labels had initiated a range of experiments. The Madison Project partnership from IBM and the major labels was a small-scale pilot of delivery of albums to home PCs (case study section 8.3.2), followed by the large scale SDMI (case study section 9.4.3), where over 200 member companies from the computing, music, and consumer electronics industries attempted to build a secure digital music format to replace the increasingly popular MP3. SDMI was announced in 1998 with Leonardo Chiariglione, who previously led the MPEG standardisation process, appointed as leader. The goal of SDMI was to create a secure technical standard, and the members spent the next three years engaged in the task. There was initial optimism, a release of a technical standard described as technically secure, which was then cracked by Ed Felten, a professor of computer science at Stanford, with SDMI eventually being put on hiatus on 18 May 2001, unable to spur the widespread adoption of a secure technical standard.

The relationship between entrepreneurs and the RIAA was hostile at this time. There was a range of unauthorised products which brought with it an initial legal offensive to curtail these unauthorised products, and at the same time, there was a lack of perceived reasonable licensing opportunities for entrepreneurial companies to access major label content (case study section 9.4.1). Lawsuits were common from the RIAA against these entrepreneurial efforts (case study section 9.4.1).

Amidst this public battle, privately, there appeared genuine attempts to explore digital distribution between the labels and entrepreneurs. Meeting the record label heads in private, for example, the CEO of Napster, Hank Barry, came close to achieving licensing agreements (see case study 9.7.7), but uncertainty regarding royalty rates, the business model, previous acrimony between parties, and impact upon CD sales all ultimately resulted in the major labels not engaging and legitimising digital products such as Napster and Kazaa.

Along with the lawsuits, the major labels by 2000 had increasingly engaged in a significant amount of digital acquisitions (see case study section 10.3) and themselves were now jockeying for position with respect to the future of digital music, with examples such as Universal Vivendi's purchase of mp3.com and Bertlesmann AG's (owner of the major label BMG) alliance with Napster on 1 November 2000 (see case study section 9.7.8). The uncertainty of digital music distribution appeared to recede, and in its place the major labels were themselves attempting to control online distribution channels.

Despite the activity, there was still yet no way to legally download the majority of major label content in 2000, leading to a Senate inquiry as to why young entrepreneurial companies were not able to get licenses to sell major label content online (see case study section 10.2). Under increasing pressure and also wanting to themselves capitalise on the opportunity of online digital music distribution (see case study section 10.2), the major labels launched their own music software products in MusicNet (launched 4 December 2001) and PressPlay (launched January 2002).

Figure 6.18 MusicNet and Press Play advertisinb

By mid-2002, these products had failed and revealed a range of problems, including the need to have a complete library of all major label content; antitrust concerns, with the major labels owning music and also controlling music distribution; and problems with this software with respect to usability (see case study section 10.3.2). At the end of 2000, apart from sporadic attempts such as e-music and Real Audio, there were no compelling large catalogue major label online purchasing experiences yet available.

Whilst a common perspective is that the major record labels were slow to see the future of digital music, based on the many opinions of the experts interviewed in this research (including many competing entrepreneurs) as well as the detail of the case study, this view is not supported. The major labels from a very early time began to explore the capacity of digital music (see case study sections 7.1, 7.2, 8.4, 9.3), but, due to a number of characteristics, the transition took longer than some commentators and entrepreneurs anticipated or expected. There are a number of reasons for why the transition took longer. These are summarised in this research as follows:

1. The source of innovation did not emerge from the music industry's existing partnerships with retailers or the consumer electronics industry. This required the major record labels first to adjust these existing relationships and create new ones with IT companies such as Apple (case study sections 8.4, 9.4.3, 10.4, 10.5). As a consequence, neither industry had familiarity or sensibility with the other, and the new technology required dramatically different relationships.

2. The transition required establishing new digital contracts and standards with their own artists, with little direct precedent and widespread artist scepticism regarding acceptable royalty rates (case study 9.4.3).

3. There are also perhaps fundamental differences in the speed of innovation between the music industry and the IT industries, which slowed down the transition. For the music industry, innovation was not related to the release of new products but instead to maximisation of value from existing products via back catalogues. The top selling CD between 2000 and 2010 was the Beatles 1 album, a collection of songs recorded and released in the 1960s and by 2001 at least 50 years old. Highlighting the difference between the record industry and IT and computing industries, by contrast, Apple or IBM could not rerelease a 50-year-old computer (case study section 9.4.3).

4. Significant control and authority issues impacted negotiations between the major labels and entrepreneurs. The RIAA and the major labels viewed entrepreneurial startups with a sense of ambush, as illegitimate, and initially as competitors (case study sections 9.4.1, 9.7.6, 10.3). Hostility was also promoted by entrepreneurs such as Michael Robertson, who described the labels as slow to change (see case study 9.6). This

impacted negotiations and made finding agreement more difficult than what it would prove with latter products such as Spotify, who were not engaged in this activity.

5. Perhaps more than any other issue that made the transition difficult for the major labels was that online distribution did not offer the major labels any clear or obvious business model. And particularly, online distribution did not offer a business model that was comparable in revenues to the CD model (see case study section 9.4, 10.3). Despite the record industry having a long history of being able to transition to new technologies, this particular transition was extremely negative in respect to revenues – from the CD, which was the most lucrative format of all time, at its all-time highest revenues, to a new distribution technology with almost zero revenues, and one that even in best projections would not offer revenues anywhere near comparable to the CD. This made the transition a difficult one for the major labels.

6.4.1.7.2 The consumer electronics industry

Another complementary perspective to consider is the consumer electronics industry. Prior to the emergence of online music, the consumer electronics industry had a strong relationship with the record industry. The clearest example of this was Sony. Sony had a history of compelling and powerful innovation, particularly in portable music. The Walkman, the CD, and the DiscMan were all Sony technologies, which had both defined the success of the record industry and what portable music meant for much of the world. The strength of Sony was such that in 1998 it was voted as the world's most recognised brand (see case study sections 4.8, 5.1, 6.1, 7.5, 9.3, 11.3.6 for a detailed history of Sony, MiniDisc, Walkman, and DiscMan, as well as more generally Sony's innovation philosophy). Sony had also attempted to strengthen its capacity to capitalise on new technologies too. After the failed BETA format of the 1980s, Sony purchased CBS records to become the first consumer electronics company to also control content (discussed in detail in case study section 9.3). With the Walkman brand, a major stake in content and a promoted internal culture of innovation, Sony were well placed to seek the future prior to the first portable digital music players.

Sony, however, and the consumer electronics industry more generally, faltered with respect to portable digital music players. Despite their history, portable digital music players required different technologies, and Sony did not have any advantage with the new technology of the internet, PC hardware, or software. Particularly, the new players required software, and Sony were not a software authority. Their legacy was as a hardware innovator, and their products required nominal software. This characteristic became more obvious with the release of more players.

Whilst it wasn't entirely clear in 1998, portable digital music players based around PC components required strong organised software that made the experience better across both the portable player and the PC. Apple's solution was one that embraced the PC as a central device and created effective software to improve the value of the portable music player. Sony entirely missed this, releasing players that whilst impressive from a hardware design perspective were dysfunctional as a user experience. Sony's first player received widespread consumer derision on account of problematic software and their particular decision to not allow the player to play MP3 natively due to copyright concerns.

The important role of software, and particularly the importance of the relationship between the PC and portable music players, appeared more obvious to some PC hardware component manufacturers. In June 2000, Creative announced their PC strategy, which identified the PC and software as a critical component. In January 2001, Jobs announced Apple's digital hub strategy, describing the relationship as critical.

The advantage appeared to have shifted to those companies that were natively PC companies, and who understood consumer behaviour with PCs. This, of course, wasn't enough in and of itself enough to achieve success (best noted with the failure of Microsoft), but it was soon leveraged by Apple for dramatic success.

Cary Sherman again, giving insight into the complexity of the changing source of innovation reflects on how IT companies came to dislodge the role of consumer electronics companies during this time:

> *Well, we knew that the IT industry was going to be getting in this space, but I think we looked at it more as software-enabled delivery systems, not necessarily products. So early on, the major labels chose IBM to do a test, an experimental delivery system for albums. It was called the Madison Project. They did it in San Diego, but they [the labels] went to what was then the biggest and best and most highly thought-of computer company [IBM], and they worked with IBM for album delivery, and it was going to be full albums, and it was going to have album art. It was going to be replicating the physical experience, except online. Everybody thought of this as delivering [of music] to a computer. So the IBM role was not to create new music players; it was to create delivery and distribution systems. Apple coming out with the iPod was a game changer, and yes the major labels did get a heads-up because Steve Jobs came asking for rights, but I don't think most of us looked at the IT industry as the source of product innovation. IT was going to be service innovation or delivery innovation. But it turns out [it came from] the IT industry*

> *– well, Apple in particular. Nobody else did the job that Apple did in terms of creating new devices. (C. Sherman, personal communication June 27, 2013).*

6.4.1.7.3 Physical retailers and distributors

During this time, CD retailers, such as independent record stores or, more significantly, large-scale chain retailers such as Virgin Megastores and Tower Records, had a critical role in the transition and were a source of feedback on developments. Much like consumer electronics companies, retailers did not have native skills in software. Their skills and resources were physical logistics and physical retailing. Despite this, the significance of digital was not unknown to these companies. Virgin set up its own Virgin Radio product online very early, and it was in retailers such as Tower Record that Todd Rundgren demonstrated his Patronet and CD-interactive software in 1994 and 1995 as a forebear to later developments.

Record retailers appeared to be exploring digital, with for the most part no native understanding or competitive advantage with respect to the new digital technology, and they were also now at a competitive disadvantage due to their control of physical and intellectual assets that were rapidly becoming a limitation. They were "below zero" with respect to their capacity to engage in new technologies, due to the need to also maintain their existing technologies; as a result, often in *Billboard* particularly, the effort was assigned to warding off and downplaying the threat of new technology in comparison to engaging in the change. Pamela Horowitz, the CEO of National Association of Retail Merchandisers, was often vocal in *Billboard* regarding the risks and uncertainties of digital distribution at this time, as well as promoting that the labels needed to support retailers on account of how important their relationship had been in the past (see for example case study section 8.4).

Physical retailers ultimately failed, and, corresponding with the popularity of Napster, Kazaa, and the growth in revenues of iTunes, Tower Records declared bankruptcy in 2004, and the majority of Virgin Megastores were closed by 2007, reflecting a wider decline in music retailing.

6.4.1.7.4 Summary

Portable digital music players were not a simple extension of the existing CD industry. Digital distribution and portable music players required a complete reconfiguration of the industry in ways that were not possible to predict. That is, the emergence of these new complementary configurations and industry relationships could not simply be established by analogy or by expectation. Much like the technology, these relationships emerged as a process of trial and error, as understanding of innovation shifted and key industry partners learnt of where they were best placed. This was perhaps more than any other type of change, the most difficult as well as the source of the most resistance. It also led to the record retail industry capitulating, the consumer electronics industry losing their status as a major innovator and the computer industry emerging as the new source of product innovation.

6.4.1.8 Cultural feedback

The final level of socioeconomic variation and selection described in the model chapter was that described as culture. The use of the term "culture" is consistent with what is introduced by Garud et al. (2013, p. 797) and broadly represents the economic, political, and legal environment in which the technology is placed. These conditions have an impact on the design criteria and value of the technology.

Digital music was a confronting technology from a cultural perspective. The availability of MP3 files on the internet was a powerful technology that challenged the long held and accepted cultural value of music. These technologies created a powerful cultural question: Was downloading music stealing?

The previously accepted cultural expectations regarding the price of music as well as the requirement to purchase was questioned with the availability of these new technologies. Prior to the internet, paying for recorded music from record stores was both an expectation (and even a celebrated) cultural experience and norm. With access to Napster, available on standard PC hardware in most homes, digital music became an ethical dilemma.

It was also a complicated time with respect to the conflict between cultural expectations and new technological capacities. Jeff Levy is a prime example of this. As a University of Oregon student in 1996–1997, and with his dorm having fast internet, Levy began trading files on his PC with other members of an Internet Relay Chat group (see case study section 9.2.4). The University IT administrator saw the increased bandwidth and reported Levy to local authorities for copyright infringement. Levy was prosecuted for copyright infringement by the U.S. government for sharing software and music. Levy was found guilty of copyright infringement and sentenced to a fine and an extended ban from using the internet.

This event took place prior to Napster, and for Levy the rise of Napster in 1999 soon became a source of anguish and felt sharply unjust. With him and his family having gone through the ordeal of being sued by the U.S. government for sharing copyrighted material online, Levy now watched news reports of Napster users of the same age brazenly and proudly declaring how much music they had pirated. These users on news reports were openly declaring they had downloaded more than Levy ever did, to national TV audiences, and where Levy had a criminal record, an internet ban, and a fine for his actions, the reports would end and move on to other news with no consequence for those involved. The issue was a complicated moral one.

Since then, and with the increased availability of easy-to-use cheap music services that offer major label material, expectation regarding copyright has been reinstated, and the consumer behaviour of pirating appears to have receded from mainstream audiences, although the practice requires ongoing enforcement. In retrospect, 1998–2002 has been described as a confusing time with regard to this behaviour – a time where "an entire generation committed the same crime" (Witt, 2016). Amidst this lifeworld of 1998–2002, these technologies brought significant cultural uncertainty, and this section ends with the behaviour of downloading rampant but, prior to iTunes, no clear obvious channel to purchase music legitimately over the internet.

6.4.1.9 Summary of variation and selection

The variation selection feedback during this time was ferocious on all levels discussed. The range of developments was such that digital music transcended a product category to at times capture the attention of much of the world media. The above has discussed four alternative levels of feedback that had an impact on the development of innovation. The large volume of products and new events at this time revealed problems and issues across all of these levels that offered feedback for further development. It would soon be Apple, with the iPod, iTunes, and the iTunes Music Store, that would address many of the problems that emerged from these previous products.

6.4.2 **Marker 2: Accumulation in capacity of the lifeworld continues, and this creates further opportunities for exaptation and combination, with components of greater capacity becoming available.**

The trial and error that characterised this time brought with it an accumulating amount of understanding about better performing products and designs. After the emergence of products such as Napster and the large volume of flash-based portable music players, there was a clearer sense of problems created by the technology.

Amidst the trial and error, new capacities emerged too. The creation of the new jukebox category of players that utilised laptop computer hard drives was a further example of new exaptation through this time, and one that appeared to be counter to the expectations of the importance of flash storage held by the consumer electronics industry. The incremental improvement in technologies that was discussed in the establishment lifeworld continued, and new performance that was previously unavailable could be used for new products and services.

6.4.3 **Summary**

The development lifeworld, recognised as events between 1997 and 2001, is a time of dramatic development for portable digital music players and digital music more generally. The large volume of events during this time created a trial-and-error process that revealed new behaviour, problems, and expectations across a range of socioeconomic criteria. Throughout this time, whilst there were many claims to innovation, it remained elusive. Whilst there were examples that got close, such as Napster, Kazaa, and to a lesser extent the Diamond Rio, each had ultimately revealed new problems and then receded in importance.

The large amount of failure and experimentation of this time had resulted ultimately in no product as a sustained innovation, but it had set the foundation for what was next. This was perhaps best encapsulated by an article in the *Economist* in April 2001, six months before the release of the iPod, which offered a critique of the accumulating precedent in digital music to that point. Recognising the earlier pioneering expectations of a dramatic revolution in digital music that had by this point now also revealed the failures of Napster, the dot-com crash, and the increasing uncertainty with respect to whether this digital revolution would occur, the author suggested that innovation would require more than simply suggesting that digital music innovation was inevitable:

> Just because the Internet and electronic entertainment coexist doesn't mean one is the automatic illuminant of the other. The true merit of most supposed techno-marvels usually abides in a realm underlying the surface traits, waiting for original minds to discover revolutionary uses. (White, 2001)

Despite the large volume of trial and error during this lifeworld, and the accumulation both in understanding of socioeconomic conditions and available technologies, this lifeworld ends with major innovation yet to emerge.

6.5 Innovation lifeworld

The fourth and final lifeworld is when dramatic innovation is achieved. After previous lifeworld conditions have limited a technology to imagination description (prehistory lifeworld), then adolescent creation (establishment lifeworld), to development where there is a lot of trial and error but innovation remains elusive (development lifeworld), a new design emerges in this fourth lifeworld, titled innovation lifeworld, to achieve dramatic success.

The innovation lifeworld is described with the emergence of a dominant design (Anderson & Tushman, 1990), which is a single product that comes to achieve widespread adoption, capturing the vast majority of value of the innovation of the entire domain, having the effect of disrupting many previous entrepreneurs from the domain (Abernathy, 1979; Sahal, 1981). Whilst relying on the accumulated learning and capacity of the previous lifeworld, which provides many conditions and technologies critical to the creation of the dominant design, the dominant design is an extension of this and requires new insight and advance – what Usher refers to as the task of “critical revision and mastery” (Usher, 1954). The design may emerge as a result of furthering accumulation where the lifeworld offers new components or new performance not possible at previous times. This design, once realised, emerges amidst uncertainty and a great deal of alternative designs, but as a process will establish dominance over the entire class of products to then become recognised as a dramatic innovation becoming difficult to dislodge.

The iPod became a clear dominant design. Between the release of the first iPod on 23 October 2001, and the end of this research 31 December 2007, the iPod dominated the portable music player market. In 2007, the final year of this study, 52.6 million iPods were sold, responsible for 72.4% of all portable music player sales (Krazit, 2007). The iPod was both a consumer and cultural phenomenon.

Within two of years of Apple releasing the iPod along with Macintosh-based library software iTunes (iTunes was released first, 10 months prior to the iPod), it created the iTunes Music Store, where users could pay to download individual tracks and albums from major label artists. The combination of these three – a highly effective portable music player, aligned desktop/laptop music library software, and the ability to buy major label content represented a complete digital music experience that resonated in the market. By 2003, Apple had also bifurcated the iPod from a single product into a range of iPod products, and also released a Windows PC version of iTunes, which opened iPod to a much larger market.

Drawing upon many common technologies, Apple created a product that achieved uncommon success. The way in which this design became dominant, as well as its impact, will be discussed below.

6.5.1 **Creation**

Apple relied heavily on the state of available technologies to create the iPod. In a technical analysis of the components of the iPod, the conclusion was that “much of the underlying iPod design was performed by outside companies” (Sherman, 2002). Apple used external suppliers for a wide variety of internal components. The battery came from Sony, software came from a company called Pixo, the analog-digital converter came from Wolfson electronics, and flash memory came from Sharp. A prototype 1.8 inch thick 5 GB hard drive from Toshiba was also utilised. The case study describes in detail the large number of external component companies

Apple utilised to create the iPod. The use of these varying component suppliers relied upon the strategy of combination. When asked if the hard drive was the source of innovation, for example, Rubinstein instead identifies that it wasn't one component but both the *availability* and *performance* of this wide range of products:

> *With these kind of things it's always the combination of the technology. So without firewire you couldn't have moved the data fast enough. Without the hard drive – the size or storage – either you didn't have the size, or you didn't have the storage capacity right. Without the display technology you couldn't have a good enough display; you'd have a one-line instead of having a multiline display. Without the battery technology your battery life would have sucked … advancement of integrated silicon, or system on a chip, really important. So it really took all of those technologies, plus the software technologies, the user interface with the wheel and all that. … So I think it was the combination of all of those and such a great form factor, really great UI with the wheel, that really created the first product that was for more than just geeks. (J. Rubinstein, personal communication, July 9, 2013)*

Rubinstein further explains that the availability of components was dynamic, and that Apple had waited for the emergence of particular capabilities:

> *Anything we did at Apple we did in a heartbeat, right, we did with a sense of urgency, but we never did a product before its time. Or we tried not to. So we waited a while till the technologies would really support the kind of product we wanted to build. So we waited quite a few months, until I found the 1.8 inch hard drive, and during that time displays had matured, battery technology had matured, so it was kind of just the right moment in time to go do it. (J. Rubinstein, personal communication, July 9, 2013)*

With a short development time and utilising iTunes, which was released in January 2001, the iPod was released on 23 October 2001 (see Figure 6.19).

Figure 6.19 The first iPod

6.5.2 **Uniqueness**

Whilst there was a strong reliance on the available components from external sources, the design of the iPod did not exist ready-made waiting to be discovered. The iPod as a combination of components was an achievement for Apple. Apple had a long history of focus on industrial design, marketing, and consumer computing products with a superior ease of use to competitors. These characteristics manifested in the design of the iPod, and it was a product unique to Apple's particular sensibilities. Whilst Rubinstein notes combination as critical to the creation of the iPod, later, he gave focus to this, describing the iPod not as random combination, but the choices of combination being the hard work of innovation:

> *I think there was a lot of innovation around it. First of all, it was the integration of just the right technologies at just the right time, and that's an art, not a science. There is an art form to that. You got to know what to put in, and what to not put in. I think we hit the sweet spot on form factor, on battery life, on cost. I mean all of those were kind of sweet spots. And then I think our whole concept around how the software on the Mac interacted with the software on the device, that the Mac made the device much more valuable than it would be all on its own. And I think that was very innovative for us. (J. Rubinstein, personal communication, July 9, 2013).*

This research identifies a number of key unique achievements of the iPod in comparison to competitive portable music players of the time. These are discussed in detail in the case study but are summarised below:

1. The new Toshiba hard drive gave it the size profile of flash players (it fits in your pocket) but had the memory capacity of hard drive players (it holds your entire music library).

2. Apple optimised the relationship between the portable music player and PC/Macintosh library software (the digital hub strategy).

3. Apple was skilled as an integrated hardware and software manufacturer. Most other IT companies were either hardware only (e.g., Dell) or software only (e.g., Microsoft). The integration between hardware and software allowed Apple to achieve a far superior user experience than other players where portable players and music library software were designed separately.

4. The scroll wheel design was a unique design of Apple's for portable music players. Apple imitated the design from a Bang and Olufsen telephone. It provided a superior interface to button scroll menus of all rival portable players.

5. The iPod was created using premium materials. Most rival players were made of plastic. The only other player on the market to use aluminium was the high-end Bang and Olufsen MP3 player, which had a significant price premium.

6. The iPod played all popular music formats. Some rivals, including Microsoft's music library software and Sony's portable music player both did not easily or natively play MP3.

7. Firewire gave transfer speed an advantage between the player and PC compared to players using USB1. Firewire was Apple's own creation for desktop video and was standard for iMacs and iBooks. Using this for the iPod gave them an advantage. Apple then transferred to USB when iTunes was released to PC.

8. The design of the iPod proved iconic (particularly the white headphones), influenced by seminal designer Dieter Rams.

9. Apple spent 10 times more money on marketing compared to any other portable digital music player company, and the colourful iPod silhouette marketing campaign also proved iconic, winning numerous awards.

10. Despite having all of these superior features to other players, Apple's iPod price was comparable to other players (it was not the cheapest or most expensive). This was particularly the case with the release of the iPod Mini and Nano, which competed at the lower end of the price market.

11. Apple outcompeted the market on strategy, turning any initial advantage of the first model iPod into powerful wide-ranging success. Apple quickly bifurcated the iPod into a product line to outflank competitors across the entire portable player market.

6.5.3 The impact of precedent on Apple's design

To create their unique achievement in the iPod, Apple utilised a great deal of accumulated understanding from the market. As discussed in previous sections, by the time Apple entered the portable music player market, the category had an almost four-year history, with the first players released in early 1998, along with more general developments such as Napster, Kazaa, MusicNet, and PressPlay. There had been a great deal written in reviews and general commentary about the wide variety of players available along with developments of the music industry. Many paths had been explored, and there was a banking amount of precedent about both the value these products delivered as well as the issues with them. Despite the accumulating understanding, at the time Apple entered the market, there was no clear dominant product. As Jobs noted in the introductory keynote for the iPod, despite the competition, "no one had found the recipe; there is no clear market leader for digital music" (Jobs 2001).

The design of the iPod appeared to identify and avoid many of the mistakes and issues of competitors that entered earlier. For example, Apple's iPod played a range of leading audio formats, including MP3, natively. Sony, by contrast, sought to offer a proprietary format that complicated the user experience. By 2003, based on market feedback, Sony too had adopted this strategy and released a player natively capable of playing MP3.

More generally, the state of available portable players released prior to the iPod also appear to have had a direct impact on the design of the iPod. For example, the scroll wheel interface, a defining characteristic of the iPod and acknowledged as a revolutionary user interface by Jobs (see case study section 11.4), was conceived by Phill Schiller after using other competitor portable music players on the marketplace and finding it frustrating to press a button hundreds of times to navigate to a particular song (see case study section 10.5.2). In finding a solution to this problem, Schiller suggested the design of the Bang and Olufsen BeoCom telephone, which had a scroll wheel interface with a button in the middle to navigate a library of phone numbers.

Along with identifying and avoiding problems and limitations with existing players, Apple also appeared to imitate features and characteristics from technologies that worked and were viewed by consumers fondly. For example, the “autosync” process between iTunes and an iPod, which made the relationship between player and PC software very easy (“plug, whirr, done” was the catch line offered by Jobs), appeared to imitate a similar syncing process of Palm Pilot’s handheld organiser, which itself had links to previous Apple software (see case study section 10.5.3). Palm Pilot’s autosync feature looked and functioned in a similar manner to the iTunes and iPod sync feature. Another example is the software on the iPod. Apple utilised a tree search structure for the software on the iPod (meaning that searching for an artist led to a menu of their albums, which led to a menu of their songs). This was similar to the software design of Creative’s players, to the extent that Creative sued Apple for patent infringement for copying this design layout. In 2005 Apple settled with Creative, paying them $100 million (case study section 11.3.1).

More generally, iTunes imitated many features of MusicMatch, the then leader of PC music library software. MusicMatch was reviewed as the best PC library software by Walter Mossberg prior to the release of iTunes; it avoided the design and functionality problems of Windows Music Player and Real Audio (see case study section 9.2.3). MusicMatch offered a complete capacity to rip a CD, store it in a library, create playlists, and then burn this to a new CD-R. Apple’s iTunes similarly offered this functionality in a simple and effective way.

Perhaps most notably, Apple’s decision to initially not embrace flash memory and instead use the small profile Toshiba hard drive in the iPod was counter to most competition at the time. Whilst the generally accepted view within the industry was of the importance of flash as the memory standard, clear consumer frustration had emerged with flash players at the time because they could only store a maximum of six to 15 songs. In contrast, the jukebox category established by the Compaq PJB-100, discussed in the previous lifeworld, had received consumer praise on account of the capacity to store over 1,000 songs, but limitations of these players were noted to be both their bulk and weight along with battery problems and slow transfer speeds (see case study section 9.3). Utilising the 1.8 inch hard drive from Toshiba, with its 5 GB memory capacity, allowed Apple to create a much smaller player than any other jukebox players while retaining the capacity to hold 1,000 songs. Drawing from existing market, Jobs’s promoted marketing headline for the iPod of “1,000 songs in your pocket” was almost identical to the marketing headline of Compaq’s PJB-100 player a few years before: “Can you carry your entire music collection in your pocket? Yes you can”. But where the PJB-100 player didn’t actually fit in a standard-sized pocket and was reviewed as large, utilising the new Toshiba hard drive and with thoughtful component design the iPod achieved a much smaller form factor, which delivered more value to users.

There were also other features that made the iPod superior to other players. Much like identifying limitations with existing flash players with respect to storage capacity, Apple was also creative in finding ways to improve on characteristics of other jukebox players. For example, the iPod utilised a technical design that would switch off the spinning hard drive at certain times to save battery and, combined with the more advanced Sony battery, the iPod battery lasted 8 to 10 hours, where other players required AA batteries to be replaced every two hours – and in some cases more often. Equally, Apple's proprietary Firewire standard from their previous work in desktop video offered far faster transfer speeds from PCs to the player, allowing users to transfer songs from iTunes to iPod in a much faster time than competitors.

The accumulative outcome of this focus on improvement was that Apple delivered a product that was similar to other players in concept but far superior in performance on many characteristics.

Whilst Apple didn't create the portable music player market, it had the focus and the skills to deliver a far superior product than competitors. Rubinstein identifies that Apple's achievement with the iPod did not come in trying to create a radically different player in concept but, instead, a radically different player in performance. Apple's dogmatic focus on improvement meant taking existing, common concepts, often the same as that used by competitors, and offering a new configuration that dramatically improved the user experience. Rubinstein describes this focus on making decisions to improve user experience as a key mindset and constant focus for Apple at the time, giving another example of it to make the point:

> *Absolutely. I mean you know when we did the PC version, you know, the thing you always had trouble with PCs is you had to load the drivers and everything, right? So we figured out a way, since the iPod was a mass storage device, when you plugged it in, it would load the drivers automatically. Instead of having to go up someplace else or have a CD or whatever, it would download the drivers. It just made sense because if you have a mass storage device why would you not do it? So whenever you plugged it in to a PC that didn't have the drivers on it, it would ask if you wanted to load those drivers. I mean just logical things like that made it a much better user experience (J. Rubinstein, personal communication, July 9, 2013).*

Furthering this focus, Apple established the iTunes Music Store. In the process of doing so, Apple was able to achieve an unprecedented licensing agreement with the major labels to offer consumers a product that matched their preferred behaviour.

Access to competitive licenses of major label content was a source of frustration for previous entrepreneurs, and Jobs achieved what no others had done in obtaining agreement by negotiating with the labels for landmark usage rights, which allowed users to burn copies of purchased tracks (see case study section 11.2). Whilst there were precedents from eMusic selling 99-cent songs, no company had achieved such a wide-scale agreement from the major labels. Analysing why it was Jobs who achieved this licensing agreement, where all others failed, including entrepreneurs and leaders from consumer electronics companies and IT companies, offers a number of suggestions:

1. Jobs had credibility as the CEO of both Apple, which was as worldwide leader in personal computing innovation, and Pixar, itself a creative studio of content. Jobs had a level of credibility that few other young entrepreneurs or IT companies had.

2. iTunes offered the labels a margin-based online sales model rather than the subscription model of other services, which was more aligned with their history.

3. The labels were likely more receptive to partner for online digital distribution at this stage, based on their own extensive experimentation at this point – they had not licensed Napster, created their own failed distribution services, and were under increasing pressure for anti-competitive behaviour.

4. Apple designed a more complete music delivery process than competitors, one that was designed in collaboration with the major labels rather than offered to consumers first without consultation, which made the labels perhaps more receptive to partnership.

As an outcome of this negotiation, Apple received unprecedented major label rights, but also the design of iTunes and the iPod included a number of piracy controls (or digital rights management) where Apple made design trade-offs to find an acceptable outcome for the major labels. By 2008, with the labels more comfortable, Jobs pushed for the removal of all Digital Rights Management (DRM), and these tracks began to be sold at a premium in iTunes.

This describes the context of the creation of the iPod, iTunes, and the iTunes Music Store. Below describes the effect of the release of the iPod and Apple’s strategy between 2001 and 2007.

6.5.4 **The “process” of a dominant design**

The iPod became a dominant design eclipsing all other competition by a significant margin. However, this outcome was not immediate or obvious at the initial launch in 2001. The iPod’s status as a dominant design emerged as a process, driven in part by Apple’s continuing decisions that extended its initial advantage to widespread dominance. These issues will be discussed below, beginning with initial reaction.

At launch, there was a mixed reaction to the iPod. There was a notable range of journalist reviews that described the product as superior to other portable players and lauded it for its ease of use. However, few reviews described it as the revolution Jobs promoted, and there were other reviews that suggested it was not particularly revolutionary at all (see case study section 10.5.5). Along with this, there were initial consumer reactions that viewed iPod as not particularly innovative. These reviews critiqued its features as too similar to other existing players in the market, such as Creative's line of payers, which were available at a lower price (one forum poster offering the iPod as acronym "Idiots Price Our Devices"). The context suggested that whilst the player was good, it wasn't clear that it was a radical innovation.

In an article titled "The Race to Catch iPod", the competition of Microsoft and Sony was described as credible. It was noted that the iPod had spurred competition, and Sony was planning to launch a new iPod competitor called the Network Walkman, which would be smaller, lighter, and have a greater capacity than the iPod, being able to hold up to 13,000 songs (*Economist*, 2004).

However, once consumers began to purchase the device and use it, there were also positive reviews that described its ease of use, design, and quality as far superior to competitors. The iPod quickly established itself as a leading player in the jukebox hard drive player market and the market overall. The iPod was selling one in every four portable players on the market and was viewed as a success, with Apple selling over 2 million iPods by the end of 2003. It still wasn't entirely clear, though, if Apple could continue this initial success, with recognition of the likely response from competition. Mp3newswire founder Richard Menta described in December 2003 the task of Apple retaining its 50% market share as "an extremely challenging task as competitors get better" (Menta, 2003). In retrospect, 2003 iPod sales were small relative to what was to come.

In 2003 and 2004, Apple brought together the complete experience – Apple offered a lower priced iPod Mini, along with the release of iTunes Music Store, and iTunes for Windows. This shifted the scale of sales dramatically, as the initial success of the iPod transferred to a mass market, the iPod moving digital players beyond early niches. Reflecting this movement, there were significant jumps in the scale of iPod sales in 2004, 2005, and 2006, with each year being a sharp jump from the previous; for example, the sale in 2005 of 46 million iPods was more than the total iPod sales from 2001 to 2004. The graph below in Figure 6.20, which charts iPod sales per quarter, further demonstrates the sales increases both yearly and with quarterly fluctuation highlighting how sales would increase in December each year.

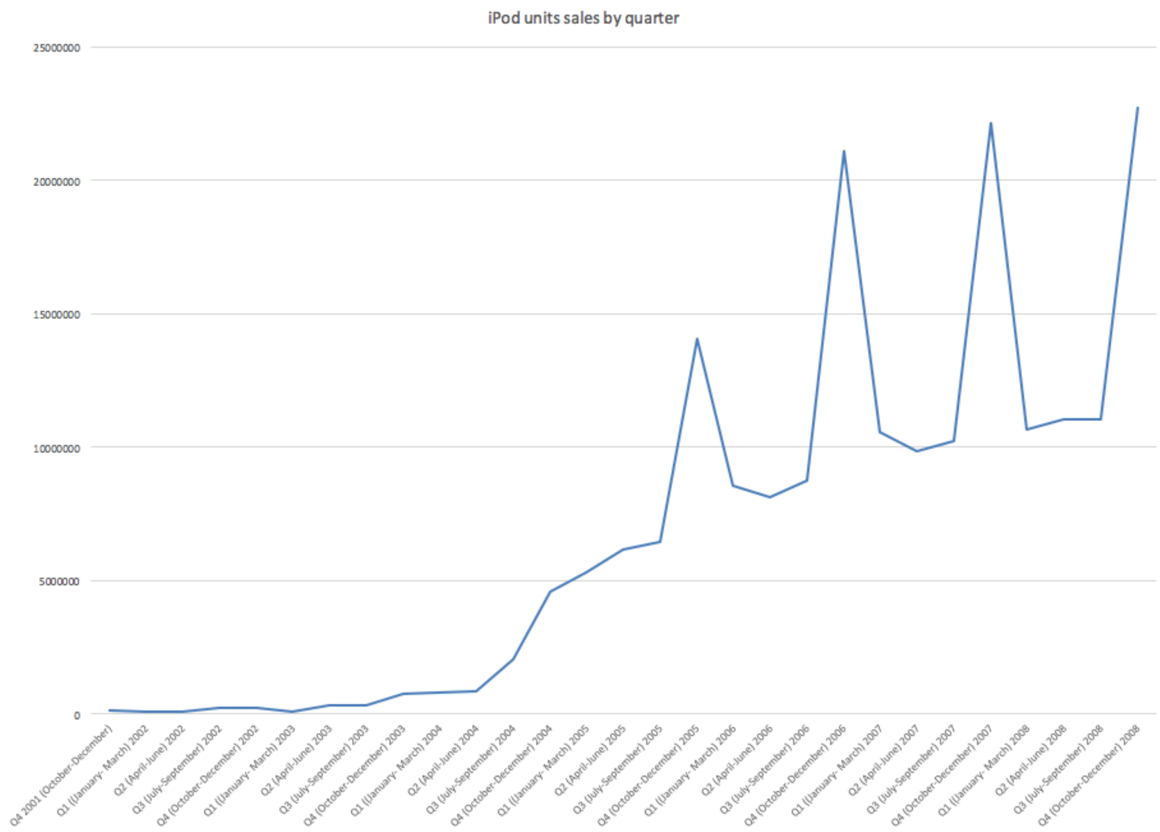


Figure 6.20 iPod unit sales by quarter

There was a strong focus on incremental improvement by Apple at this time, continually releasing updated models with greater storage capacity, superior hardware design, and more features (each new iPod model is discussed at length in case study section 11.4). The effect of this improvement was vast, with the original iPod classic model, for example, moving from an original 5 GB hard drive capacity retailing for $399 in 2001 to a 120 GB capacity retailing for $249 in 2007. Comparing the two, the later model iPod is 60 times bigger than the original model, whilst also 38% cheaper (see case study section 11.4).

Apple also pursued an aggressive bifurcation strategy for the iPod between 2004 and 2008, shifting it from a single product to a product range. As a range of products with different prices and features, the iPod became a product for both niche and mass markets, resulting ultimately in Apple’s domination of the entire portable music player market. The timeline of the release of the iPod into an iPod product range corresponds to a significant shift in consumer response from 2003 onwards, with Figure 6.21 mapping cumulative iPod sales against the release of individual iPod models.

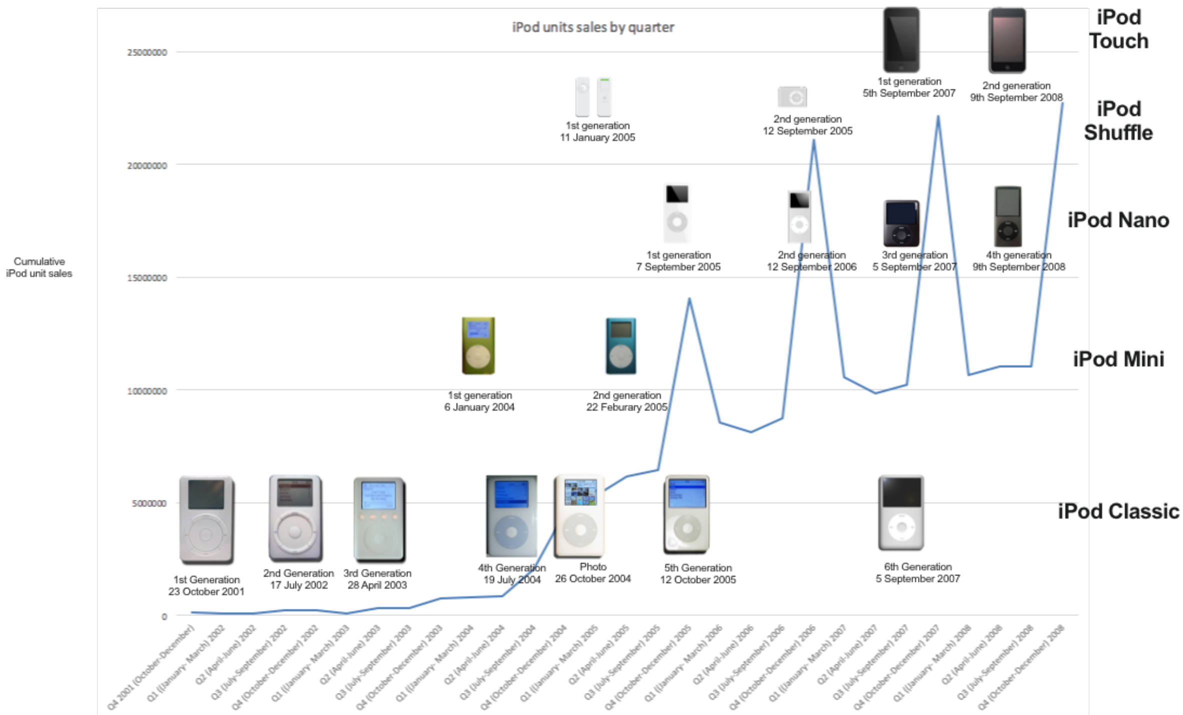


Figure 6.21 iPod sales overlaid with iPod models

Jon Rubinstein discusses the reasoning for this aggressive release schedule, along with the constant focus on new products, as one of competitive threat:

> *We always thought that Sony was going to blow us out of the water. I mean, it shocked me year after year after year that Sony didn't deliver something that blew us away. Because by all rights they should have. They had the brand. Aside from Sony they had the Walkman brand – they'd sold 300 million Walkmans. It should have been a no-brainer for them. But for some reason, they never executed. Now, you can't rely on your competition not executing for strategy – that's a bad strategy. So we always assumed that they were going to kick our butt. And so we had a tremendous sense of urgency, very fast pace, which is why during the four or five years I ran iPod that we came out with so many different versions and three levels, right, and just keep iterating on all of them. So it was really important. (J. Rubinstein, personal communication, July 9, 2013)*

This proved a powerful strategy that took the success of the iPod beyond any initial advantage that was created in the first model.

6.5.5 **The impact of a dominant design**

The iPod had an impact on competition. After the iPod was released, there was a shakeout of competition in the marketplace, with some notable failures. A wide variety of smaller companies such as iJam and Evolution all left the market. Most notably, Diamond Audio, the creators of the PMP 300, which was viewed as one of the best early players, also capitulated, being sold to SonicBlue, and then eventually discontinuing these players. Players from Dell, Intel, Samsung, Panasonic, and Phillips did not achieve significant adoption, and the release of the iPod relegated these companies to offering cheap commodity players before eventually withdrawing from the market. There was also a significant shift in the amount of coverage of the digital music domain at this time, with many of the conferences or dedicated news websites no longer continuing from 2002 onwards (the mp3.com summit and Webnoize conferences did not run, and Wired's MP3 Rocks the Web website stopped publishing in 2003).

Despite the changing market, there was still a constant stream of new players at this time, all challenging the iPod (see figure 6.22 below for a range of alternatives). The emergence of the portable music player market as a mainstream product brought with it continued new competitive threats for Apple. Microsoft was perhaps the highest profile new entrant, releasing the Zune player. The Zune was similar to the iPod and appeared briefly to gain momentum on account of its marketing budget, but consumer response quickly dissipated, and Microsoft eventually discontinued the Zune and left the portable music player market.

This was an ongoing theme for many companies and releases throughout this time. Every six months from mid-2004, mp3newswire.net founder Richard Menta would document the new portable players, the newest and best offerings from competitors such as Sony, Creative, Microsoft, Samsung, and others. Six months later Menta would conclude all had failed to beat the iPod. By 2007, not only was it clear how dramatic Apple's success was, with the iPod selling three out of every four portable players in the entire market, but also how successful the iPod had been in outflanking the competition to turn an initial advantage into a dramatic golden run of success: "Since 2004 we have run our bi-annual iPod Killer Christmas/Summer series. During this period we have reported on 215 portable players and in all of that time NOT one single iPod Killer has emerged from the bunch" (Menta, 2007). The players themselves improved in quality, but none was able to achieve lasting success against the iPod.

Figure 6.22 Alternative Portable music players post 2001

Those that found relative success in the marketplace in this time did so in a number of ways. Many companies emerged with similar products to the iPod but competed on geographic popularity – players from Creative and iRiver offered similar features to the iPod that were popular in particular locations such as Singapore. Another competitor, Sandisk, emerged as the second largest competitor in the marketplace on account of its strategic control of flash memory (see detailed overview of Sandisk in case study section 11.3.3). Sandisk was the creator of flash memory technology, and during this time slowly moved down the production chain, first as the owner of technical patents of flash, earning royalties from flash component manufacturers, then as a manufacturer itself, creating flash memory components for portable players from companies such as Samsung, and then as a creator of their own portable players, selling these directly to consumers. The successful achievement of competitive advantage as a result of their vertical integration led Sandisk to claim the second most successful portable music player company based on revenues.

Along with this, other companies continued to pursue niche markets, offering more targeted players for children, luxury, novelty, or sports, as documented in Figure 6.23. None of these found lasting adoption in the market.

Figure 6.23 Ongoing portable players designed for specific niches

By 2004, the iPod was beginning to be recognised as a significant achievement, both from those within Apple as well as externally (see case study section 11.4). This continued as further market demand unfolded. By the end boundary date of the end of 2007, the iPod was being recognised as a dramatic, iconic innovation. The iPod won numerous consumer awards, including "best gadget of all time" from consumer tech journalism website T3 (Malik, 2007) and gadget of the decade from wired.com (Wired, 31 December 2009). Apple had capitalised on available conditions in this innovation lifeworld to create the iPod, and then through a mix of strategy decisions built this into a powerful dominant design that captured 75% of the entire market.

6.6 Chapter Summary

This chapter has presented events related to portable digital music players in four alternative lifeworlds, describing how lifeworld conditions at different times offered varying capacity to achieve innovation. Summarising these four lifeworlds and the specific events related to portable digital music players, the lifeworld conditions are summarised below:

Prehistory lifeworld – Imaginative descriptions of portable digital music players emerged from entrepreneurs (Kane Kramer's IXI player) as well as in fiction (the Chippy hoax from a children's TV program), but products remained impossible to build on account of missing technological capacity.

Establishment lifeworld – The first prototypes (the NEC Silicon Chip Audio player and the Audio Highway Listen Up Player) followed by the first market-released products emerged (the MPMan and the Diamond Rio). These products are described as combinations of pre-existing technology, with the lifeworld at the time offering technologies that made these products capable as combinations, with many of these required technologies having long trajectories prior, often in alternative industries.

Development lifeworld – With a tangible technical design offered with the MPMan and Diamond Rio, there was a dramatic amount of new activity and new entrants. New portable digital music players were released from companies in a variety of industries, including the consumer electronics, IT component, and PC industries, with the design variations of the designs of the MPMan and the Diamond Rio. At the same time, a large number of dramatic events occurred more generally in digital music. The internet soon led to the popularity of the MP3 and then Napster, along with the popularity of CD burning. The record industry found itself under significant duress on account of the threat of piracy, and at this same time CD sales were reaching new unprecedented revenues.

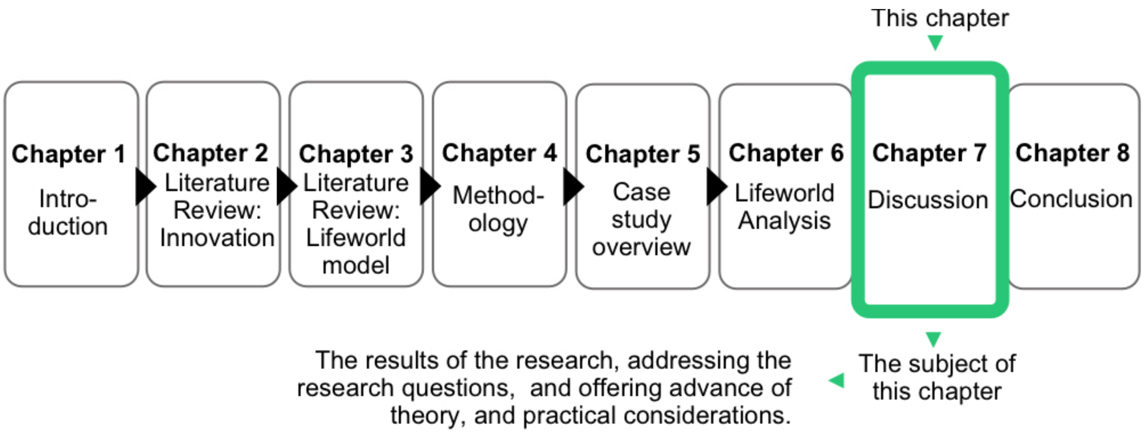
The large amount of new activity created significant trial-and-error processes, which exposed problems across a number of socioeconomic criteria, and despite the large amount of activity, lasting innovation remained elusive. At the end of this lifeworld, there was no clear market leader in portable digital music players, and the domain faced continued uncertainty.

Innovation lifeworld – Drawing from the large amount of precedent and navigating through many of the problems that impacted previous products and services, Apple released iTunes, soon followed by the iPod. This was the first hardware- and software-integrated solution, and along with the superior characteristics of the iPod (capacity to hold 1,000 songs, superior battery, display, design, marketing), it soon established a competitive advantage in the market. Apple then followed this with the creation of the iTunes Music Store, released iTunes on the Microsoft platform, and initiated a significant bifurcation strategy to make the iPod a product range covering a range of price points and features. With this activity, from 2003 onwards, the iPod began to move beyond being a successful niche product to being the dramatic dominant design, building the portable music player into a mainstream consumer product. Apple's dominance also led to a large-scale shakeout, as many competitors left the market unable to dislodge Apple from their dominant position, with the iPod recognised as a landmark innovation and Apple capturing 75% of the market at the close of this research.

The next chapter, titled Discussion, will address the research questions of this study, exploring the significance of the lifeworld, combination and exaptation, and how the dynamics of the lifeworld impacted the capacity to achieve innovation in portable digital music player technology at different times.

Chapter 7

Discussion



7.0 Introduction

This chapter will reflect on the lifeworld concept and will specifically answer the research questions. As part of this reflection, this chapter will also describe a number of theoretical issues that emerge from the case study.

The lifeworld model is an attempt to describe the influence of external environment through the innovation lifecycle of a particular technology. As discussed in the literature review, theoretically, this is in response to the heroic innovation perspective that assigns the achievement of innovation exclusively to the unique skills and thoughts of individual protagonists with little regard to conditions within which these protagonists are situated. The lifeworld concept is also a response to the acknowledged limitations of the theory of technological innovation systems, which also has an almost exclusive focus on the internal design and characteristics of the system being the source of innovation, rather than wider technologies, people, objects and events external to the system. In response to these issues, the lifeworld model attempted to cast a broader view, describing the wider context in which a particular technology and people attempting to create a particular technology are situated, including things external, not initially or at times obviously relevant to the technology in focus. It was suggested, with reference to the importance of the theories of combination and exaptation, that these things surrounding the technology can have an influence or perhaps are even critical to the creation of the technology as well as achievement of innovation. Exploring the lifeworld was the motive of this study.

The research questions reflect the focus on the lifeworld, and they provide the structure of this chapter. To recall the four research questions of this study, they are:

1. How significant is the lifeworld to events and innovation in the case study?
2. How are combination and exaptation relevant in the development of innovation?
3. What is the relationship between the internal domain and the external lifeworld?
4. How do the dynamics of the lifeworld impact innovation?

Below, these four questions will be answered in detail, drawing on a range of events from the case study as well as a number of wider theories in the innovation literature that offer insight.

Note that whilst the chapter is structured around the research questions, throughout this chapter, a detailed discussion is offered that explores the theoretical issues and implications emerging from each question.

7.1 Research question 1: How significant is the lifeworld to events and innovation in the case study?

The case study suggests that the external lifeworld is critically important to the development of portable digital music player technology. Many of the events that proved critical to the development of portable digital music players did not originate for the specific purpose of portable digital music players or from the preceding history of development of portable digital music players. Events such as Napster (created by a university student), mp3.com (created by an entrepreneur watching popular search terms on the internet), Diamond Rio and MPMan (created by computer component companies), and the iPod (created by a PC company) are all examples of this. These individuals and companies were responsible for events that emerged often as dramatic shocks to the record industry and those working on the development of portable digital music player technology, unprecedented and unexpected at the time of their emergence.

Drawing from the case study and the previous chapter, there are a number of detailed examples that highlight the role of the lifeworld as significant. First, pragmatically the lifeworld as an important source of development and innovation is reflected in the difficulty of constructing the event history narrative tracing events prospectively rather than retrospectively. Second, the significance of the lifeworld can also be described in the important characteristic of uncertainty that defined most development. Both will be discussed below.

The difficulty of case study construction as an example of the importance of the lifeworld

The practical process of constructing the event history narrative of this research offers a close tangible example of the importance of the lifeworld. The case study is very long and describes a significant number of events related to the development of portable digital music players in detail. The event history narrative began with the earliest events and moved forward in time, constructing the event history prospectively, as opposed to beginning with the outcome and retracing events. As a result, the construction of the event history narrative offers close confirmation of the importance of the lifeworld, as often new important developments did not simply extend from the description that was already provided. Instead, new developments emerged from entirely new sources that often had no previous recognition in the narrative. For example, the case study described developments from Sony in detail over an extended time: their creation of the Walkman (case study section 5.1), the CD (case study section 6.1), portable CD Discman (case study section 6.3), MiniDisc (case study section 7.5), and their strong internal culture of pursuit of innovation (case study section 9.3). With this history, Sony was a strong and powerful authority with respect to portable music up until 1998, when the first portable digital music players were released. Highlighting the importance of the lifeworld, however, despite the case study describing each of these events in detail and describing Sony's innovative capacity in detail, Sony proved not to be the source of inception of the portable digital music player technology. To cover this long narrative of events related to Sony's successful history, and more generally the consumer electronics industry, was then to miss the start of the portable music player market, which emerged from the companies Diamond, Saehan, and Creative, who themselves had a history as computer component manufacturers. For thoroughness, Saehan, Diamond, and Creative were also then covered in detail in the case study, but soon these were supplanted by new entrants such as Sandisk and Apple, which were also then described in detail too.

The accumulation of new events from the external lifeworld required an almost constant resetting of much of the event history narrative of the case study, with new events emerging from new sources. Each new event often came from an external source that engaged portable digital music technology, from its own unique history and trajectory in a different independent part of the lifeworld. This is represented in Figure 7.1 below, which offers a visual representation of how whilst the recording industry and consumer electronics industry were in a strong partnership prior to digital downloading and portable music players, it was from the internal source of IT companies and computer component companies, as well as software entrepreneurs, that new events would emerge. It was the IT industry that emerged from its own history in the lifeworld not related to digital music, to intersect the domain of digital music and cause both the difficulty of transition as well as ultimately being the key source of innovation.

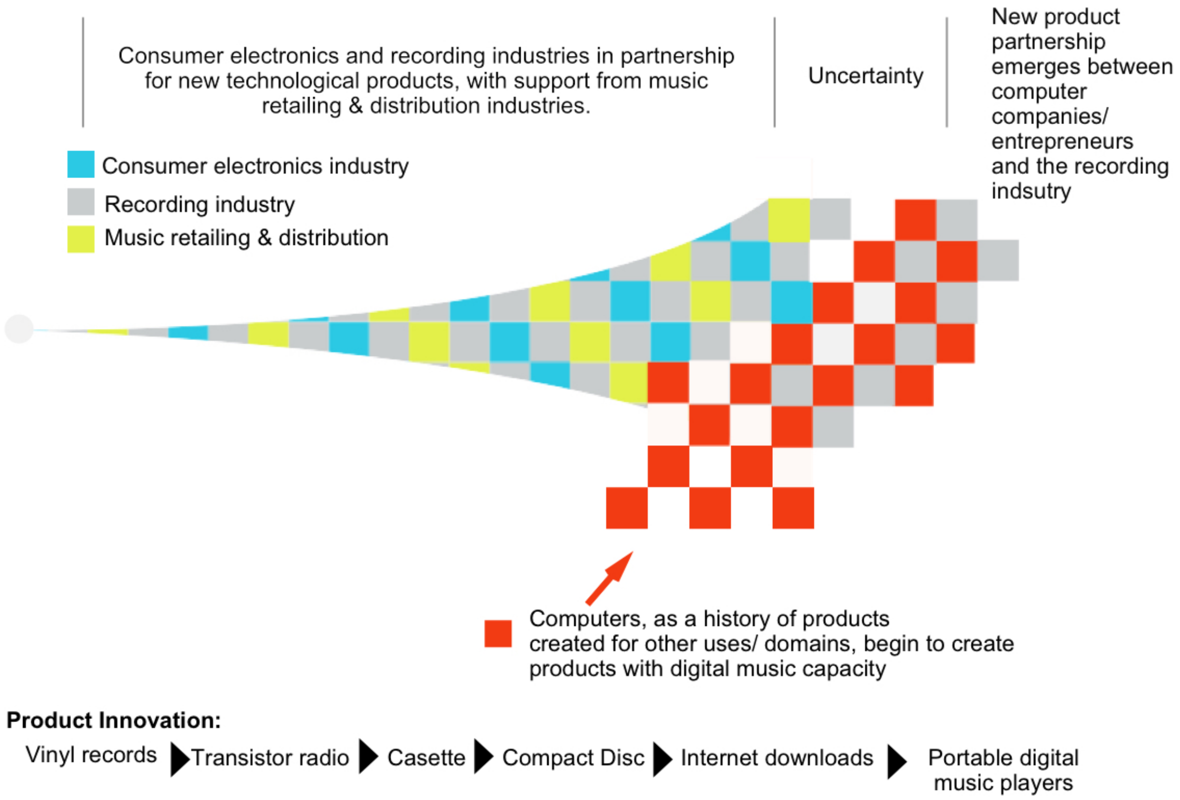


Figure 7.1 How hew developments emerged from the lifeworld

Whilst there are many examples of process in the case study, including the brief description of Sony above, Apple is perhaps the most important example. Apple had a long history as a PC manufacturer (and this was covered in a number of case study sections, including 4.5, 9.2,1), but prior to 2001 with the release of iTunes and iPod, Apple did not have a significant link to digital music. If the event history narrative had concluded any time prior to 2001, Apple's relevance would only draw passing mention, with no clear evidence of a looming capacity to achieve dramatic innovation in portable digital music players. In real time, there was no obvious sense that the PC or IT industries were the clear source of dramatic innovation, and that it would be Apple who capitalised and created these conditions more than any other company.

This is a powerful example of the role of the lifeworld, and it is also reflected in the sentiment of key protagonists. Apple's potential for innovation in portable digital music players and digital music more generally was not inherently obvious or forecast by anyone within the domain, and in expert interviews of this research, reflection described the unexpected nature of Apple's involvement and ultimate achievements. Jeff Patterson, for example, founder of IUMA, one of the early popular sources of music on the internet, and an early pioneer deeply engaged in digital music prior to Apple, describes how Apple's engagement was unexpected at the time:

> *It was kind of a shock when they [Apple] went that direction [released iTunes and iPod]. I think it kind of surprised a lot of people. They were computers for graphic artists, so the fact that they came out with this consumer device that was just a music player was kind of an odd sort of thing, but then when you look at how it ends up being, how they end up moving in to content, and how they then set the precedent for the 99 cent download. They had probably a bigger impact on the labels and how they approached online music than almost any other company. (Jeff Patterson, personal communication June 26, 2013).*

More generally, Cary Sherman, the CEO of the RIAA, also reflected on the expectations of the recording industry, who attempted to create innovation in partnership with the consumer electronics industry in a similar way to their previous partnerships with cassette and CD technologies, and initially viewed the IT industry as having a supplementary role:

> *Well we knew that the IT industry was going to be getting in this space, but I think we looked at it more as software enabled delivery systems, not necessarily products. So, early on, the major labels chose IBM to do a what would you call it, it was a test, an experimental delivery system for albums, it was called the Madison Project and they did it in San Diego but they went to what was then the biggest and best and most highly thought of computer company and they worked with IBM for album delivery and it was going to be full albums and it was going to have album art it was going to be replicating the physical experience except online. Everybody thought of this as delivering to a computer. So the IBM role was not to create new music players, it was to create delivery and distribution systems. Apple coming out with the iPod was a game changer and yes the major labels did get a heads up because Steve Jobs came asking for rights, but I don't think most of us looked at the IT industry as the source of product innovation. It more was going to be service innovation or delivery innovation. But it turns out the IT industry [was the source of innovation], well Apple in particular, nobody else did the job that Apple did in terms of creating new devices. (C. Sherman, personal communication June 27, 2013).*

For the recording industry, for example, as described in the previous lifeworld analysis chapter, the embrace of digital distribution was not simply an extension of their previous industry structure and partnerships with external suppliers, but instead required a total reconfiguration of relationships with partners, suppliers, and even consumers on account of the new source of innovation being from IT companies in the lifeworld.

Technologies developing external to the domain in focus became critical as a source of new events and innovation as they connected to the domain in focus, shifting expectations and the source of innovation. This highlights the role of the lifeworld and the experience of the researcher writing the event history narrative, as well as those cited protagonists involved in the case, confirming that the external environment represented as the lifeworld was a powerful and an important determinant of new events and innovation.

Uncertainty as an example of the importance of the lifeworld

Another example of the significance of the lifeworld, and how important events emerged not exclusively or even predominantly from within the domain but from external sources in the lifeworld were the conditions of uncertainty that characterised development.

For all actors, digital music and portable digital music players constantly developed under pervasive conditions of uncertainty, with no one having a clear sense of what was to come next, or that ultimately that it would be a product like the iPod that emerged as the successful innovation. New events such as Napster, Kazaa, iTunes, and iPod constantly emerged as shocks, similar to the kind described by Van de Ven et al. (1999), where ongoing assessment and analysis did not account for these coming events prospectively. With these events not visible or connected to previous narrative or expectations regarding what was to occur, new events that emerged from the lifeworld constantly rendered previous analysis wrong and incomplete.

As a result, the narrative and assessment of the transition was constantly in flux, with new events emerging from the lifeworld to be followed by waves of narrative, analysis, and forecast describing and making sense of these new events, only for this narrative to often then be totally oblivious to the next event and to miss what was to come. For example, there was a general positive recognition of the importance of digital music in the record industry from a very early stage. In 1994, many key industry figures described digital distribution as a dramatic looming change for the record industry, albeit, given the time, with reference to satellite transmission or services similar to cable TV. See Table 7.1 which draws from the case study, and also chapter 6.

Table 7.1 Record label executive insights 1994

Executive	**Insight**
Gary Gersh, President, Capitol Records:	The industry "is on the verge of a massive revolution that will rewrite the ways we receive and relate to all forms of entertainment". He says Capitol is using "all of the various technologies" to collect information each week to better market its records. He says Capitol localises and micro-markets by cross-referencing the data. The label also relies on computer technology for its art department (for digital download and transmission of art files) and for improved communication between field and national staff" (Lieb, 1994).
Michael Schulhof, President, Sony Music	"The executive told retailers it takes a customer about one hour to drive to a music store, purchase a CD, bring it home, and put it into his or her player. The transmission of that same recording to the home via fiber optics – so-called 'music on demand' – will take less than five seconds" (Jeffrey, 1994, p. 6).
Peter Cox, Managing Director, EMI Music Publishing UK	"The potential is enormous. It's only a matter of time before other people take this on" (Clark-Meads, 1995, p. 12).
Danny Goldberg, President, Atlantic Records	"In general, I think these technological advances have served the music business wonderfully well … Each development in technology has caused a growth in our business and expanded music. … Suppose everything becomes cyberspace … People are still going to have to be experts at making things look interesting. There will be limitless options, so how will we market ideas? People can only look at a small fraction of the possibilities, so it will take a lot of strategizing about how to expose music" (Lieb, 16 April 1994).

These record label executives were prescient with respect to describing the general shifts about to occur. However, whilst this recognition described the importance of digital distribution at a broad level, with respect to specific products, these forecasts were oblivious to what was to come. These forecasts, for example, did not offer any warning of Napster, iPod, or iTunes.

The uncertainty was pervasive, and there are examples of “missing knowledge” emerging from even the progressive perspectives on events. Whilst the record labels were often criticised publicly for their slow embrace of digital distribution, even for those who were progressive, the uncertainty still appears pervasive. For example, in 1999, only months before Napster was released, prominent digital entrepreneur Mark Cuban declared “MP3 doomed”, suggesting that the format would not scale and would instead be replaced by streaming services from RealNetworks or Microsoft that were going to be dominant (New Media Age, 1999). Whilst Cuban was right to suggest the importance of streaming services, there was no mention of Napster or peer-to-peer, and his assessment of the death of MP3 occurred only months before Napster took MP3 popularity to dramatic new unprecedented levels.

Another example is found on the *Computer Chronicles* TV episode titled “MP3 Secrets”, which aired on 9 October 2001, exactly two weeks before the first announcement of the iPod. Larry Magid, a *Los Angeles Times* technology reporter, presented a segment that gave an overview of the best portable music players available on the market, including the Diamond Rio 500, the Nike player, and the Casio WMP 1 wristwatch. The portable music player market was well established, and whilst Magid described these players as a significant development, when completing the segment, Magid was asked, “What’s going to be next?”, and he highlighted the lack of obvious direction emerging out of these early players, despite it being only weeks until Apple announced the iPod. Magid focused not on the future importance of portable players but instead described the role of MP3 CDs:

> Well the car MP3 players those are already coming, you know so you can have it in your car. MP3 is going to explode. And of course the CD! MP3 CD, so you can have hundreds of hours, thousands of discs, and the next thing is that the music industry may start selling mp3 CDs. (Magid 2001)

These examples highlight the significant role of the lifeworld, and how events that had already occurred were not a reliable reference point for what was to come; instead new events would emerge from external sources, and the existing narrative at any given time could not foresee what was to come from events that had already occurred.

This highlights the important role of the lifeworld. Exploring this further, a theoretical concept called the “time sequence trap” (McMullen & Dimov, 2013, pp. 1491–1492) offers useful relevance. The time sequence trap is a theory that describes problems related to uncertainty and error as a result of the incremental emergence of information and understanding. Those involved make best use of what has become available at any particular point in time, but new information proves that previous analysis was based on incomplete information, leading to its error (McMullen & Dimov, 2013, pp. 1491–1492). New information reveals previous assessments to be based on "partial information", with new information not neatly and simply extending previous assessments but instead requiring totally new reconfiguration. McMullen and Dimov (2013, pp. 1491–1492) and deBono (1992, pp. 16–17) give a simple example of this issue:

> *We can play a simple game in which letters are presented one at a time. The task is always to form a known word.*
>
> *The first letter is A.*
>
> *This is followed by T to give the word AT.*
>
> *The next letter is R, which is simply added to give RAT.*
>
> *The letters represent incoming information and the total available information is used to make up a word.*
>
> *The next letter is E to give the word RATE.*
>
> *The next letter is G, which gets added to give GRATE.*
>
> *So far the new information has been easily added on to the existing structures. The next letter is T. There is no easy way this can be added on. A new word can only be formed by going back and disrupting existing structures to reassemble the letters to give TARGET.*

This example highlights that the emergence of new developments required the total reconfiguration of previous events and developments, and that at any given time, the best that could be done was to make best use of what was available, as opposed to optimise for a later development. In the case of the example, the final word of TARGET was not a simple outcome or extension of previous work.

The same occurred in the case study. Developments and events occurred as new technologies emerged from the lifeworld, with each event requiring fundamental reconfiguration of existing understanding and narrative of the development of digital music and the digital music player that occurred prior to the event itself. All parties engaged in development – entrepreneurs, journalists, the record industry, the consumer electronics industry, the IT industry and all others – had to constantly reconfigure expectations on account of new events that emerged from the lifeworld. Dramatic events would emerge to then render any previous understanding as based on partial information, reaffirming the constant presence of uncertainty.

Significantly, much like the example of the time series trap, the ultimate innovation in the iPod did not reveal itself until in full. Instead, the trajectory towards the winning innovation of the iPod and iTunes was almost invisible through the entire creation of many of its precedents, with it not clear what was to come; it is not obvious that "target" is the final word in the above example, much like it wasn't clear that iTunes and the iPod were going to be successful until this success emerged. The iPod and iTunes required a fundamental change in expectations from those who had been engaged in digital music and failed previously.

Navigating the uncertainty and avoiding previous expectations appears a successful trait of Apple, and their capacity in this regard may have been due to flexibility. Jon Rubinstein describes that at a strategy level, Apple too were navigating the uncertainty, responding to events and changes in conditions as they occurred, rather than having a predefined fixed expectation about what was to happen. Rubinstein explains Apple's flexibility:

> *We understood the long-term direction we wanted to go. I mean, we had thought about all this stuff, we had thought it through, but we didn't have a concrete plan [like] 'OK, we're going to do this, then we're going to that and then that'. We navigated through shark-infested waters and found our way to the path, and some of it was reactive to what the competition – or what we thought the competition – might be doing. Some of it was just necessitated by what was going on in the industry and what we could do and not do. And so we were trying to be very sensitive to the needs of the music companies, and I think we achieved that, and I think that's why they trusted us. (J. Rubinstein, personal communication, July 9, 2013)*

It is this flexibility that perhaps resulted in their ability to capitalise on new emerging conditions events as they occurred, rather than being constrained by expectations emerging from previous events. Such was the case with Sony, who entered earlier than Apple, released a portable player using flash memory, and then dismissed the hard drive portable player early in its development.

7.1.2 **Summary of research question 1**

With the examples and discussion above, the case study promotes that the role of the lifeworld was an important one for a particular technological innovation. New events that proved critical to the achievement of innovation in portable digital music players didn't emerge exclusively from the history and activity of those working on the technology already, but instead the source of new events, as well as ultimately innovation, in the iPod came from the surrounding lifeworld. The study has shown that the concept of the lifeworld as a description of the wider context or environment surrounding the technology in focus is an important contributor to innovation. This has theoretical implications for the technological innovation systems functions model, with the study finding that the sources of innovation often would emerge from wider sources than what could be classified as internal elements of the system of portable digital music players.

7.2 Research question 2: How is combination and exaptation relevant in the development of innovation?

Along with the role of the lifeworld explored in question 1, question 2 extended this to explore the processes and mechanisms of how things in the lifeworld connect to the domain in focus. Specifically, this question explored the role and characteristics of combination and exaptation, recognised in the technological innovation literature as being important concepts of new creation and innovation.

Consistent with the literature review, where a range of authors were noted to describe exaptation as something pervasive to radical innovation (Arthur, 2009, location 848; Constant, 1980, p. 2; Dew et al., 2004, p. 70; Mokyr, 2002; Rosenberg, 1983, p. 75; Usher, 1954, p. 50), this study finds both combination and exaptation central to creation as well as achievement of innovation of portable digital music players. The study of the lifeworld quickly seems to surface the significance of recombination and exaptation, and combination and exaptation were important mechanisms by which individuals drew available things (technologies, concepts, people) from the lifeworld and connected them to the use of digital music and portable digital music players.

There are many describable exaptation and combination events in the case study, highlighting the pervasiveness of these concepts as mechanisms of new creation. Perhaps again, though, the most compelling example and description of the importance of combination was the iPod. The iPod as a combination of technologies is described in a detailed way in the case study (see case study section 10.5), and confirmed through the direct referencing of the concept of combination as the method of creation of the iPod by one of its principle creators in Jon Rubinstein (see personal communication quotes in previous chapter).

Exploring the concept of combination and exaptation further, there are a number of key insights that emerge from the case study. These insights highlight issues of combination and exaptation of particular significance from a theoretical perspective, as well as offering relevant examples from the case study that are currently not well described in the theory.

7.2.1 The role of incremental improvement for combination and exaptation

An important theme emerging from the case study is that combination and exaptation opportunities are not uniformly available at all times, but reliant upon the availability and available capacity of technologies. An important insight emerging from the case study is the importance and relationship between incremental improvement in available technologies, and the role this has in creating exaptation and new combination opportunities.

Rather than powerful innovation being only the emergence of new components, instead the case study demonstrated that it was the incremental improvement in existing common technologies that appeared a critical determinant of new events and ultimately innovation. The most dramatic events in the development of digital music, such as the release of Napster and iTunes and the iPod, were often made possible by common technologies that recently reached new levels of performance.

This reflects the discussion in the model chapter, which highlighted that new events are a result of new levels of performance in existing technologies that enable new combinations rather than innovation relying on dramatically unique technologies. Perez (2002) discusses this concept, suggesting that emergence of new powerful technologies (described by Perez as techno-economic paradigms) are based not only on the presence of new components but importantly on the attainment of new performance in existing technologies. Perez suggests that it was not only the presence of steel that led to the industrial revolution, but *reliable* access to *cheap* steel. It was not only microelectronics that led to a computing paradigm, but *cheap* microelectronics that exhibited reliable cost and performance improvement (Perez, 2002; see also Freeman, 1991, p. 83). Cost is one performance criteria, but others may be weight, size, memory capacity, efficiency, and access. Similar recognition has been noted by other authors (see Table 7.2).

Table 7.2 Example of required performance of components

Technology	Example of required performance of components
Steam engine	"The compound steam engine had to await cheap, high quality steel. Higher pressures (and therefore greater fuel economy) in power generation required high-strength, heat resistant alloy steels. Hard alloy steels, in turn, were of limited usefulness until appropriate new machine tooling methods were developed for working them" (Rosenberg 1982, p. 62).
Bicycle	"Another new consumer product which owed its rapid growth in the 1890s partly to cheap quality steel was the bicycle. The techniques used for their manufacture before the 1920s were not yet Fordist mass production techniques, but they were certainly high volume production, taking advantage of the new potential of steel intensive products" (Freeman & Soete, 1997, location 1370).

The incremental improvement in existing technologies appears to be a key to exaptation and innovation. This appears to essentially repeat the meaning of exaptation offered by Levinthal (1998) and Adner and Levinthal (2002) and was discussed in the literature review, which identified that often the establishment of a radical new technology can be achieved by little new technology but instead the application of an existing technology to an entirely different domain. Levinthal (1998) and Adner and Levinthal (2002) also highlight that the trajectory of existing technologies creates these opportunities:

> *A technology undergoes a process of lineage evolutionary development within a given domain of application. At some juncture, that technology, or possibly set of technologies, is applied to a new domain of application. (Levinthal, 1998, p. 223)*

The conditions and trajectory that lead to the "juncture" in Levinthal's description is the focus here, though, and there is room for further description of this from the case study. The enabling conditions for exaptation of a particular technology appeared dependent upon its incremental improvement characteristics and trajectory. As these existing technologies incrementally improve, they may reach a performance that presents a "combination threshold" or "exaptation threshold"' as an opportunity for those who recognise it. The incremental improvement that eventually gave the PC music listening and library capacity, as well the incremental trajectories of components that were utilised in the iPod, will be explored below.

Whilst by 1997 onwards the PC was a powerful music listening and library tool, this capacity was one that emerged with time as a result of the achievement of new thresholds of performance in PC components. The creator of the MP3, Professor Karl Brandenburg, had a central view of this, particularly after releasing the MP3 format in 1992. Brandenburg notes that for the first two years, nothing happened. It was not until 1995–1997, when PCs with sufficiently capable components (such as Intel Pentium processors) became widely available and cheap, that the MP3 started to exhibit its powerful impact with respect to digital music downloading. Brandenburg recounts:

> *At that time [1992–1995], the complexity was still too high [for using a PC for music], for widespread application for distribution and so on. It was really once every PC was fast enough on one hand and did have the soundcard built in on the other hand that this really took off. And that again technically was the case in 1995, but really the avalanche was going in 1997. (Professor K. Brandenburg, personal communication, May 27, 2013).*

Pursuing this insight offered by Professor Brandenburg, it was the incremental improvement in performance/price of known PC components of hard drives, and processing speeds of chips that made the PC a powerful music device. Prior to this, the MP3 had found niche use for audio feeder links for the broadcast of sporting events, as well as for train and bus station announcements, and was not a technology that could be used with PCs. It was only after the PC reached capacity to play audio that the power of MP3 established itself as a format that had such a profound impact.

Beyond the increase in performance of known components, it was also the presence of new components including sound cards and the CD-RW drive that made the PC a powerful music device. The emergence of these new components can be described as exaptation. CD-RW drives, for example, emerged as an added capacity from CD-ROM PC hardware and drives, and the added capacity to copy CDs was an exaptation of these existing drives. Where historically CD replication required complicated, major industrial scale machinery, now with the emergence of these CD-RW drives, which reached new levels of affordability by 1997 (under $400 for aftermarket purchase and increasingly a standard component of new PCs) PC audiences finally had access. Cary Sherman of the RIAA, without referring to the concept of exaptation explicitly, describes this example of exaptation from the perspective of the recording industry, which brought with it new legal questions:

> *The CD audio was not made for computers, it was made for CD equipment and basically other people came along and put them into a CD-ROM standard so that copying could take place. (C. Sherman, personal communication June 27, 2013).*

The insights of Brandenburg and Sherman highlight the presence of exaptation, as well as demonstrate that these events relied upon new components, along with incremental improvement in known components in hard drive sizes and processor speeds among other improving PC components, to support this capacity.

For Apple too this discussion of incremental improvement in known technologies was important in creating the iPod. Rubinstein described how after being shown the prototype 1.8 inch hard drive at Toshiba, where Toshiba themselves were not sure what to do with the drive, he immediately connected it to the new use as a portable music player. And in describing how the iPod was created, Rubinstein focuses in on it as a combination, relying upon a range of technologies that had reached a range of reliable performance that at previous times they didn't yet have:

> *With these kind of things [creating a new technology] it's always the combination of the technology. So [in the case of iPod] without firewire you couldn't have moved the data fast enough; without the hard drive, the size or storage, either you didn't have the size or you didn't have the storage capacity right; without the display technology you couldn't have a good enough display, you'd have a one line instead of having a multiline display; without the battery technology your battery life would have sucked… The advancement of integrated silicon, or system on a chip, was really important, so it really took all of those technologies, plus the software technologies, the user interface with the wheel, and all that, So I think it was the integration of all of those with iTunes on the Mac that made it so successful. (J. Rubinstein, personal communication, July 9, 2013).*

In a later part of the interview, Rubinstein reinforces the concept of combination, as well as the timing of combination – bringing together the right combination of technologies, based on their changing performance, and offering a product with a rich mix of innovation performance:

> *I think there was a lot of innovation around it [iPod]. First of all it was the integration of just the right technologies at just the right time, and that's an art, not a science. There is an art form to that. You got to know what to put in, and what to not put in. I think we hit the sweet spot on form factor, on battery life, on cost, I mean all of those were kind of sweet spots. And then I think our whole concept around how the software on the Mac interacted with the software on the device, that the Mac made the device much more valuable than it would be all on its own. And I think that was very innovative for us. And then the introduction of iTunes, adding the cloud component to it was also*

> *extremely innovative. And you know our software update mechanisms, I mean there was all kinds of things we did that were really sort of key. (J. Rubinstein, personal communication, July 9, 2013)*

These examples from the case study highlight that incremental innovation in existing technologies appears critical to enabling new combination. Beyond the insights of Levinthal (1998) and Adner and Levinthal (1998, 2002), this concept has been noted in innovation theory previously. Kodoma (1992) refers to similar ideas in their concept of technology fusion: "Technology fusion 'blends incremental technical improvements from several previously separate fields of technology to create products that revolutionize markets' (Kodama, 1992, p. 70). This appears to reflect the characteristics of the iPod and the PC as a digital music device, as it appears that new levels of performance in existing components made a dramatic difference to the capacity to create innovation at the times when innovation emerged. All technologies in the case study had their own trajectory, where their cost, performance, reliability, and availability, were all dynamically changing. It was the change in the characteristics that brought them into a range that made them relevant to digital music and then to innovation.

These issues highlight the complex but ultimately critical relationship that incremental improvement, combination, and exaptation had to the creation of new technologies related to digital music as well as to the achievement of innovation with respect to the iPod.

7.2.2 **Theoretical ambiguity in exaptation and combination**

The above has highlighted, with reference to the second research question, the important role that exaptation and combination had with respect to events in the case study. Furthering this exploration, there are also a number of issues related to exaptation and combination that emerged from the case study that are currently not well described by the theory. These issues will now be discussed and offer a range of potential issues for future theoretical advance of the concepts of combination and exaptation.

7.2.2.1 The difference between technological combination and exaptation is not clear

The difference between technological combination and exaptation, and the relationship between the two concepts is theoretically ambiguous. From the case study, the examples above describe where a technology can be a new combination, but with this combination also contain new exaptation. The iPod for example, utilised a laptop hard drive that appears an exaptation event. But, equally, the iPod was also viewed and described as a combination of technologies, where it was not the hard drive alone that was key to the iPod but a range of technologies. In this case, there appears no clear answer theoretically as to whether this event is either an exaptation and combination or both.

This issue can be explained in part in the genesis of the concept of exaptation as a term of biological evolution (Gould & Vrba, 1982). In contrast to biology, there is greater role for combination in creating cultural artefacts such as technologies. As Arthur (2009) identifies, it is possible to create entirely new combinations of technologies at the component level – such as combining gasoline engine and bicycle parts to create the motorbike. In contrast, new exaptation events in biology occur at the species level, rather than as a unique combination of organs. This means that combination activity is more pronounced for technologies compared to biological species. This was noted by Basalla (1988), citing the work of anthropologist Alfred Kroeber to describe how in exploring the lineage of technologies compared to species, there exhibit much more frequent examples of combinations and exaptation, making evolution less discreet as a single domain. Kroeber described this as the family tree (see Figure 7.2), highlighting on the left biology and on the right the lineage of the cultural artefact that includes many more new combination (and by inference, exaptation) events.

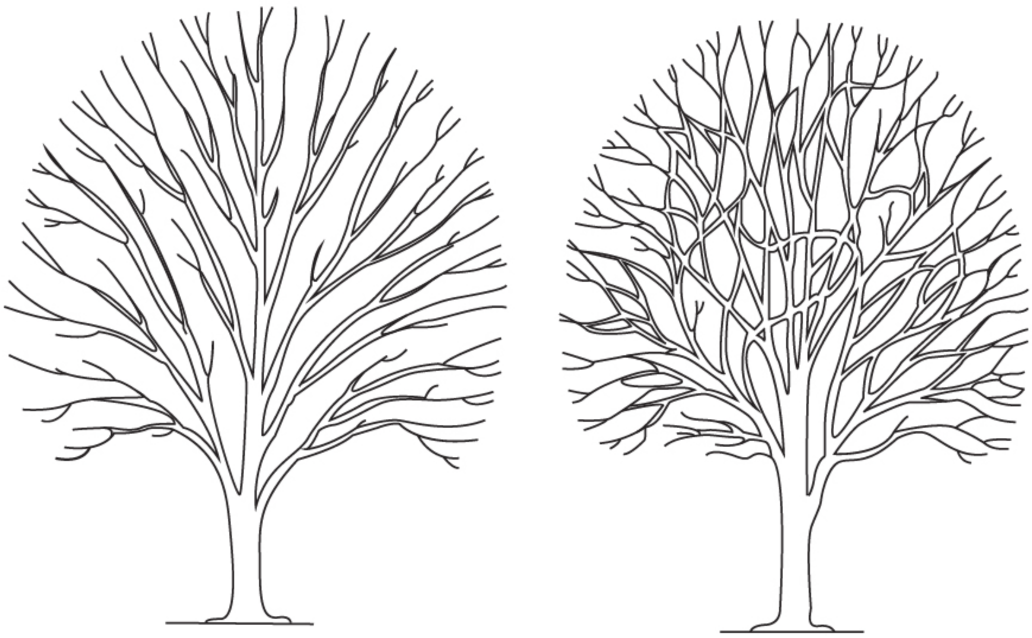


Figure 7.2 The lineage of biological species (left) compared to cultural artefacts (right) Kroeber (1948)

This issue of the difference between technological and biological exaptation is not revelatory. It is explicitly noted by Levinthal (1998) and Adner and Levinthal (2002) in their description of technological exaptation. However, emerging from the case study, there appears to be a need to explore and address this issue as a deeper theoretical issue, and providing more theoretical clarity to the difference and relationship between technological combination and exaptation appears a useful future research direction.

7.2.2.2 Conceptual exaptation

Another theoretical issue related to exaptation emerging from the case study are examples of “non-technical” exaptation. The theory of technological exaptation currently focuses on exaptation as a process related to technological components, applying existing components to uses that were previously not intended. However, in the case study, there were examples of exaptation that do not fit this technical description but rather represent examples of “concept” exaptation. For example, the first MP3 player was named the MPMan by Saehan. The “Man” suffix can be viewed as a *conceptual* exaptation from Sony’s previous history – this suffix was a powerful branding component of Sony's strong legacy of innovative audio products. "Walkman" became a worldwide powerful brand for Sony in the 1980s, and this was followed by Sony utilising the suffix extension for their next portable CD product, naming it the "Discman", which too became a powerful global brand. Whilst this wasn't a technical feature, Saehan utilised the "Man" suffix to brand their new portable digital music player as the MPMan. Repeating the description of exaptation offered by Levinthal for emphasis here, this appears to fit, albeit replacing "technology" with "brand" or more generally "concept":

> A technology undergoes a process of lineage evolutionary development within a given domain of application. At some juncture, that technology, or possibly set of technologies, is applied to a new domain of application. (Levinthal, 1998, p. 223)

The Walkman and Discman brands represent a lineage of evolutionary development. At the juncture of 1998, the "Man" Sony branding convention was then applied to the new portable digital music player technology by an independent company in Saehan creating the MPMan, which can be described as a conceptual exaptation. Whilst conceptual exaptation is not the focus of Levithal (1998) and Adner ahd Levinthal (2002), this appears a possible theoretical exploration for the theory.

7.2.2.3 Failed exaptation examples

Another area of theoretical exploration possible with respect to technological exaptation is the examples of failed exaptation in the case study. Currently in the theoretical literature, research describes exaptation almost exclusively as something that leads to successful innovation. For example, Adner and Levinthal (2002) uses the example of how Marconi created an exaptation event utilising Hertz's audio research to create a dramatic innovation in ship-to-ship communication. More generally, other exaptations (even those that predate the term) discussed in the literature review chapter also exclusively focus on successful innovation:

> The earliest steam engines pumped water from mines, the first commercial use of radio was for the sending of coded wireless messages between ships at sea and from ships to shore, and the first electronic digital computer was designed to calculate firing tables for the guns for the United States Army. (Basalla, 1988, p. 141)

These frame exaptation as a mechanism for powerful innovation.

In the case study, however, there are identifiable exaptation events that did not lead to commercially successful innovation. These events, in contrast to the existing theory, whilst appearing as exaptation, did not achieve significant innovation. At best, in some cases, they created a niche product; at worst, they soon capitulated and were withdrawn from the market entirely. Examples of this include portable digital music player watches such as the Panasonic e-Wear range (such as the SV-SD75 in Figure 7.3) and the Casio WMP-1V, described as the world's first wrist audio player. Despite the exaptation of the watch concept, and applying it to the new use as a portable music player, these products never achieved innovation and both failed.

https://goo.gl/yqJNhl

https://goo.gl/LB22H5

Figure 7.3 Portable digital music player watches

Other examples, such as the 2005 Samsung YP W3 player (see Figure 7.4), which was presented to look like jewellery, or Oakley's Thump Sunglass model (see Figure 7.5), which included a flash memory portable music player, also failed to achieve significant adoption.

https://goo.gl/jLilhk

Figure 7.4 Samsung YP W3 player designed to look like Jewellery

https://goo.gl/fZGzIX

Figure 7.5 Oakley's Thump Sunglass portable music player

These examples do not fit the current description of theory. These examples of watches, jewellery, and sunglasses as exaptations released as portable digital music players did not lead to successful innovation, with each of these products not achieving the success of the iPod.

To address this theoretically, there appears to be a need to describe exaptation more as a "mechanism of creation" as opposed to a "mechanism of innovation". The difference appears semantic but reframes the focus on innovation to be something different, allowing further exploration of whether innovation is a particular type of exaptation or perhaps in a particular type of context, as suggested by the lifeworld concept. Refining this issue is an area of future theoretical advance.

7.2.2.4 Multiple concurrent developments in the lifeworld

The final issue of theoretical ambiguity of combination and exaptation relates to the almost simultaneous emergence of multiple adjacent developments and potential directions of innovation.

A key insight from the case study is that portable digital music players did not emerge in isolation but instead represent one technology in a dramatic general context of digital music, where there were multiple dramatic events and developments occurring at the same time. These events were similar enough to be recognised under the general term of events in digital music, but distinct enough that the relationship between them was often not entirely clear, and often they were competing as alternative directions of the future and innovation itself.

The volume and diversity of events that emerged at the same time in the case study was dramatic and confronting for those involved. CD burning and ripping on consumer PCs, library software such as Winamp and MusicMatch, the peer-to-peer music sharing software of Napster and Kazaa, flash memory portable players like the Diamond Rio, hard drive jukebox players, the Sony MiniDisc, digital cassette format, and online radio and webcasting all emerged in a short period between 1997 and 2001, among other events, all as potential directions of innovation. It was not a simple choice between the CD and portable digital music player but, instead, a multitude of different alternative possible directions competing against the CD and other formats. To suggest that it was clear that the portable digital music player was the obvious direction of innovation, or even within the category of portable players that it was the component design of the iPod that would become the clear eventual source of innovation, does not do justice to Apple or those that selected other directions and products.

Sony most significantly represents the multitude of available directions and the complexity of choice that confronted those involved. With their rich history of achievement in portable digital music players, Sony were viewed as a powerful authority in portable music, with Sony advancing this perspective too, publicly promoting their history and strategic focus on innovation. However, in 1998, when the first portable players were being released, Sony pursued an entirely different alternative to the new portable digital music player technology, focusing on their own MiniDisc format. In 1998, the same year as the first portable players were released by Diamond and Saehan, Sony spent their largest ever marketing budget of any product in their history to promote the MiniDisc format across the U.S. With the portable digital music player continuing to grow, by late 1999 Sony eventually announced and then released its own portable digital player. The player when released was derided by consumers on account of Sony's decision to create a proprietary audio format and not allow the device to natively play MP3.

The ambiguity of choice and the multiple available product directions continued to make development hard, with Sony continuing to be an example of the pervasive conditions of uncertainty. For example, when hard drive players first emerged, which Apple capitalised on, using it for the iPod, Sony decided against entering the product category, remaining committed to flash memory and releasing their own branded “Memory Stick” portable music players. In 2003, just as the effect and success of the iPod as a powerful innovation was becoming clear, Keiji Kimura, senior VP at Sony, was asked why Sony hadn’t brought out a hard drive player: “We do not have any plans for such a product … But we are studying it”. The dismissal of the iPod raised intrigue for the journalist at the time: “Really? No plans? When the world leader in consumer electronics takes a pass on the hottest portable music player out there, you have to wonder what gives” (Rose, 2003). Again, in this case Sony appeared to select an alternative direction to what proved successful. By 2005, with the iPod an obvious innovation, the head of Sony’s Computer Entertainment Division, Ken Kutaragi, acknowledged publicly that the company had made some major mistakes and admitted they should have released an iPod-style product themselves (Menta, 2005).

These failures of Sony’s have been attributed to Sony’s lack of clear credibility as a software producer and their conflicted structure as both a major record label and consumer electronics company (see case study section 11.3.6), but beyond this, their decisions also demonstrate the multitude of possible directions that emerged at the same time with respect to the direction of digital music and portable digital music players particularly. There wasn’t one clear direction of advance and innovation, but many, with complicated relationships and varying expectations between them.

From the perspective of Apple, selecting from this complex of potential directions appears a significant contributor to their innovation success. Beyond creating a superior portable digital music player to competitors, one of the strengths of Apple in comparison to other companies and actors is that it found a solution that linked many of these adjacent events to achieve a product of innovation that wasn’t possible by any one product in isolation. For example, Diamond created the first popular portable music player but had little focus on PC software to load songs onto the device. Other companies in contrast focused on software only, such as MusicMatch and Microsoft creating PC library software, but often for portable devices that were produced independently. This caused a suboptimal consumer experience, to the extent that to address the issue Microsoft eventually released their own hardware in the Zune (see case study section 11.3.5).

For Apple, the focus appeared to be more complete, finding the optimal solution across multiple emerging technologies, including music library software (iTunes), online music purchasing (iTunes Music Store), and the portable player itself (iPod) expanded to a range with different characteristics and price points (iPod Mini, Nano, Shuffle, Touch). This focus on finding the optimal solution across all events was something noted by Jon Rubinstein explicitly, giving examples beyond the ones mentioned above that demonstrate Apple's focus on the entire solution:

> *That was always the concept around the iPod, right, was the combination of the cloud, of your Mac, and of the device, and all interconnected together, right, and we did Nike plus iPod was the first real man machine consumer version of man machine interface, so there was a lot of firsts we did with iPod. (J. Rubinstein, personal communication, July 9, 2013)*

In this way, the achievement of radical innovation wasn't just one key insight – it was linking a number of insights together. That is, the key to innovation was not one key technology, but finding a solution that offered a number of these key technologies linked together. The first portable music players offered some value to consumers, as too did the first library software in Winamp, and Napster and Kazaa, and all other singular products and directions. But it was in identifying the relationship between these concepts and linking them together that Apple created iTunes, then the iPod, then the iTunes Music Store, to deliver startling consumer value compared to all other individual ideas.

This concept of accumulation of multiple insights as the key to new creation has been noted in theory before. Garud and Nayyar (1994), referring to it as "transformative capacity", similarly explains how the video tape recorder can be viewed as a combination of many independent developments and avenues of previous exploration, rather one simple trajectory being the source of innovation (see Figure 7.6).

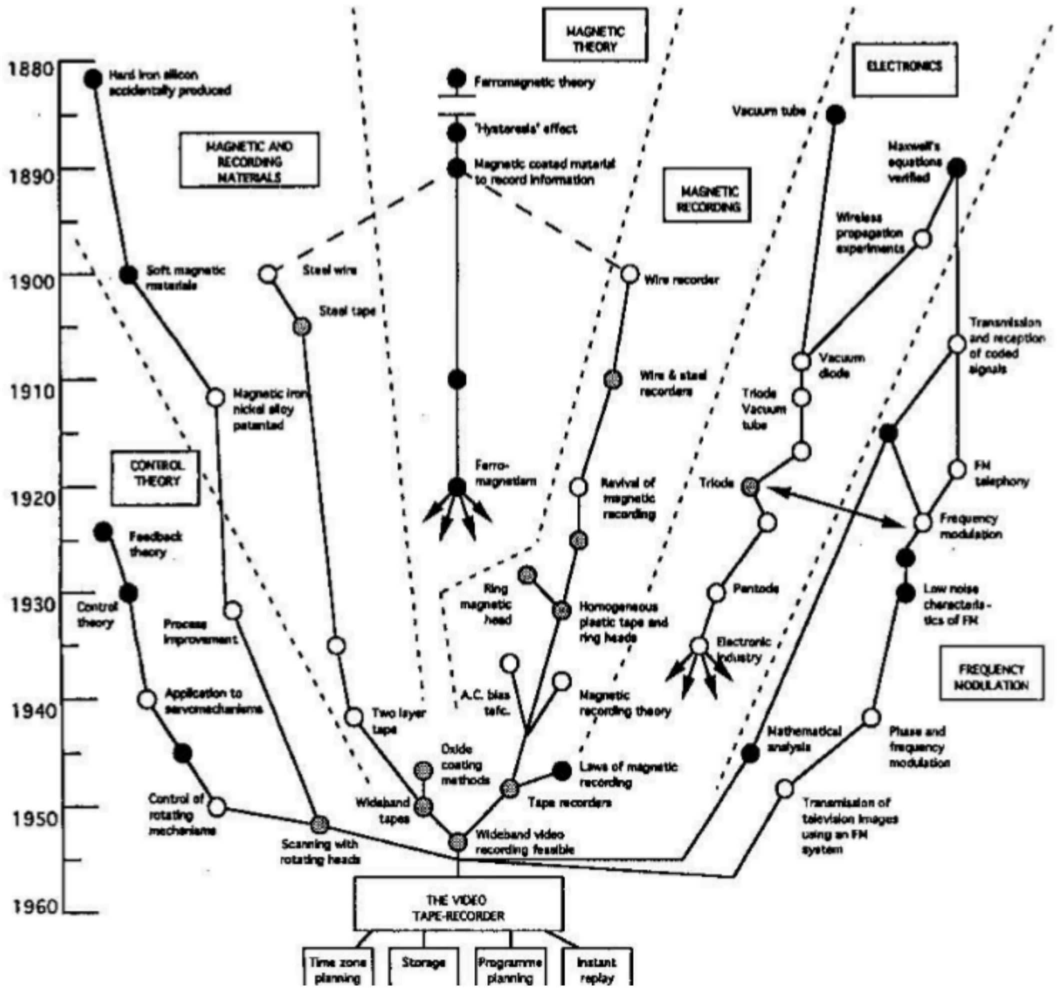


Figure 7.6 Transformative capacity for the Video Tape-Recorder (Garud and Nayyar. 1994)

Constant (1980) retracing the history of the turbo jet also described a similar phenomenon. The turbojet, much like the home video tape recorder, was a combination of a range of previous insights and avenues of development, rather than it being a singular technology in isolation (see Figure 7.7).

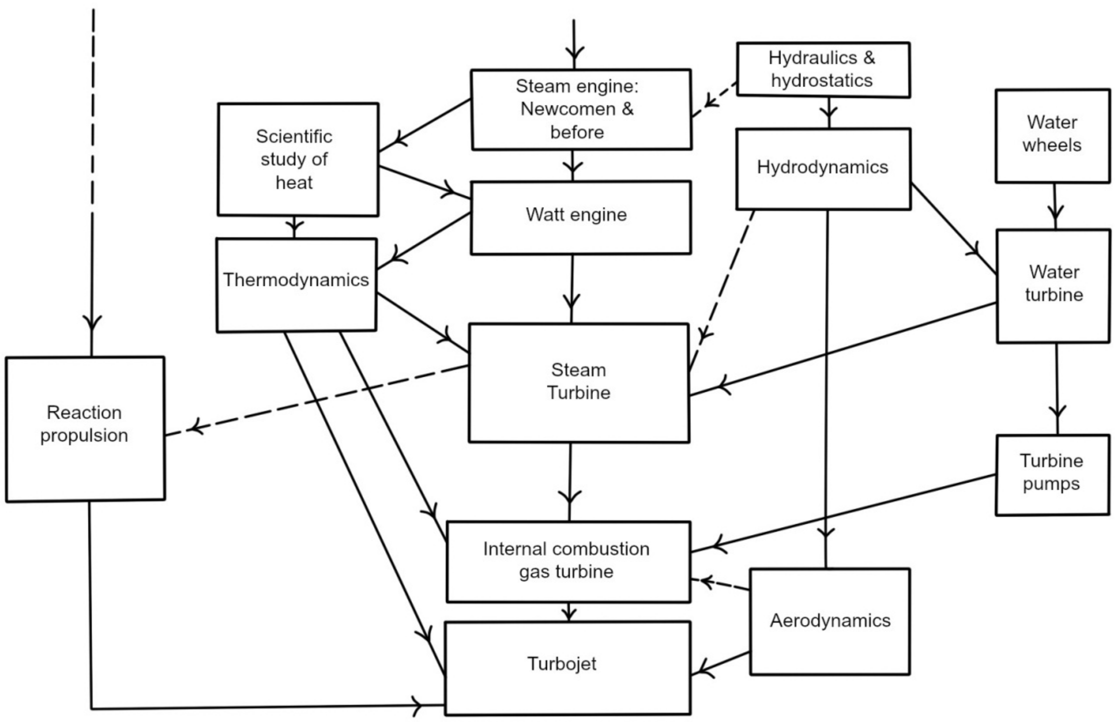


Figure 7.7 Interconnected nature of development of the Turbine Jet (Constant 1980, p. 4)

For digital music the same appears true. Between 1996 and 2002 particularly, there were a range of developments occurring, co-dependent on each other, that made it a particularly dramatic time. Events were interconnected and accumulating. Figure 7.8, much like that offered by Garud and Nayyar (1994) and Constant (1980), the general context of multiple interconnected development of the case study is presented.

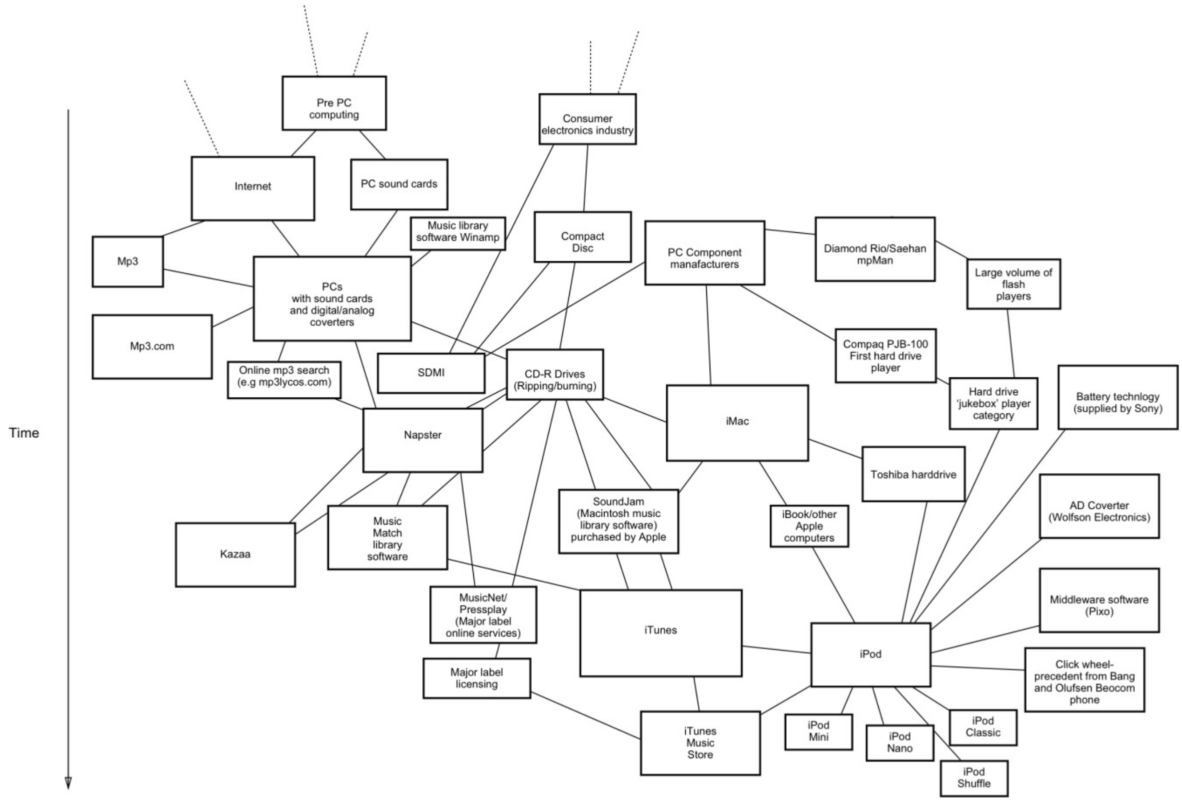


Figure 7.8 Multiple interconnected events of portable digital music players and digital music explored in this study

Recognising this interconnectedness presents theoretical complexity for the concept of combination and exaptation. It certainly promotes their significance, but it also stretches the current theoretical description, particularly of exaptation. It isn't clear that each of these events represents an exaptation. Equally, it isn't clear whether the focus of Apple on finding a combination across many events in the domain should be described as an exaptation event or a combination process, or something else. The concept of exaptation appears to generally seem relevant – Apple was a computer company that came to deliver startling digital music innovation. However, whether particular events such as the iPod, iTunes, or the iTunes Music Store represent exaptation events is not entirely theoretically clear.

Equally, whilst the model chapter discussed the concept of parallel technology, with reference to a pre-existing strong technology that the new technology would likely compete with, this does not represent this dynamic context of development. In the case study, the CD format and industry represented as this parallel technology contrasted to portable digital music player technology, but in the case study, the distinction between these two technologies didn't emerge in isolation. Instead, there was a dynamic environment with many adjacent events occurring at once and, significantly, many alternative potential directions of innovation. Apple achieved success by finding alignment across many of these events and directions, where other companies failed, often despite finding success in a particular product. Exploring this issue offers potential for further refinement and advance of the concepts of combination and exaptation.

7.2.3 **Summary of research question 2**

This concludes the discussion of research question 2, which explored the importance of combination and exaptation. The study finds that combination and exaptation proved critical to the development of portable digital music players, and they are concepts that describe a range of events in the case study. Drawing from the case study, this section also highlighted a number of theoretical ambiguities in these existing theories, which provide potential for future research. These issues are summarised as follows:

- A particular combination or exaptation is not possible at all times but instead appears to have a relationship with incremental changes in existing technologies. As such, the trajectory of existing technologies and the relationship to exaptation and combination is an issue that can be further explored in theory.
- There is a need to further articulate exaptation as a "mechanism of creation" rather than exclusively as a source of innovation – the case study presented examples of both non-technological exaptation along with failed exaptation, which are currently not represented in the theory of exaptation.
- There were many concurrent developments, each with their own trajectories, which presented innovation opportunities as more macro combinations outside of the component level, and this too is not well articulated in theory.

These issues represent current points of theoretical ambiguity with exaptation and combination emerging from the case study, and as the case study confirmed that both combination and exaptation are critically important concepts to innovation, these issues offer potential for useful future research.

7.3 Research question 3: What is the relationship between the internal domain and the external lifeworld?

As discussed in the previous two questions, the lifeworld was a critical source of new events, with these events emerging as shocks to those working within the domain. Whilst many of these events would emerge from the external environment, the internal domain represented a world of actors, events, and technologies already engaged in digital music and portable digital music players and had a critical role in the development of innovation. This third question shifts the focus to this internal domain, exploring its role in innovation, and its relationship with the lifeworld.

This question will describe these issues with reference to the role of accumulation. Accumulation is recognised in the literature and from the case study; it presents as an effective way to articulate the relationship between the internal domain and the lifeworld. Two key aspects of accumulation will be discussed: first, how accumulation occurred within the domain, making it dynamic; and second, how internal accumulation offered the lifeworld further base for events.

7.3.1 **Accumulation – internal dynamics**

The first two questions discussed in this chapter present events as significantly determined by the lifeworld – new events would not emerge exclusively from those within the domain, but instead technologies and individuals external to the domain recognised more broadly as the lifeworld would connect to the domain to cause dramatic events.

This section refines the description of the internal domain, and whilst the first two questions suggest the external lifeworld was important, the internal domain wasn't static; over time it accumulated a different capacity and understanding of the role of digital technologies and how innovation could be achieved.

The internal domain, record labels, consumer electronics companies, and music retailers, for example, would respond to new events, shifting expectations, relationships, and performance criteria over time as new events emerged. As events such as Napster, Kazaa, and portable digital music players emerged, the record labels and the domain, more generally, dynamically responded to and changed to these technologies over time. Whilst the consumer electronics industry appeared to miss the start of the portable digital music player market, after the first portables were released by Diamond and Saehan, the consumer electronics industry soon responded, and new players were released by a range of consumer electronics companies that previously sold transistor radios, cassette tapes, and CD players, like Sony, JVC, and Zenith. Whilst these companies no longer had a significant advantage on account of the fact that new conditions favoured IT component companies, they do represent how the internal environment is malleable and adjusts to new events.

This was perhaps best represented by the record labels themselves. Often lambasted in the public domain for their lack of embrace of digital distribution, the record industry over time was able to entirely reconfigure its structure and relationships to embrace new digital technology. Today, revenues from digital distribution are the record industry's largest revenue source (RIAA, 2016), and they have emerged from what has been a dramatic transformation over the past 20 years. What proved important to the record labels' survival through this time was their capacity to change and shift their own sentiment on new emerging criteria, leading ultimately to the full embrace of digital technology and distribution.

Within the record industry at any given time through this transition, there were a range of perspectives, beliefs and experiments occurring with respect to digital music, its likelihood of importance, and the urgency to respond to these events – and this was a major determinant of innovation. The state of views within the domain regarding the transformation – sentiments, expectations, experience – was a key determinant of how new events that emerged from the lifeworld were interpreted. And as more events occurred, the record industry, as too the consumer electronics industry and all others in the domain, would respond to these issues in a more decisive or ultimately innovative way.

Perhaps this is best represented in the unprecedented licensing agreement achieved by Jobs and Apple to establish the iTunes Music Store. Gaining access to legitimate and competitive licenses to sell major label songs online was a major limitation and source of failure for early entrepreneurs and large companies like Microsoft. In contrast to these previous failures, Jobs achieved this licensing agreement working with the labels.

Explaining why it was Jobs, analysis suggests that he had credibility due to his previous experience (see case study section 11.2), but this section will also describe this as an outcome of the accumulating and dynamically changing expectations of digital music within the domain. By the time Jobs worked with the labels, the labels had the previous experience of SDMI, lawsuits, Napster, Senate inquiries, Kazaa, and the closely directed but ultimately failing MusicNet and Pressplay software. Whilst the record labels at various times through this experimentation had tried varying avenues of advance, the accumulating understanding may have made the labels more receptive to licensing in 2001 than they were previously.

By the time Jobs engaged the record labels, they had a rich history of experimentation in digital music distribution, with a range of avenues explored including SDMI, the Madison Project, litigation with Napster and Kazaa, a Senate inquiry with regards to licensing, and software attempts in MusicNet and Pressplay. When asked whether these earlier events, and in particular Napster, had an influence on the agreement with Apple, Cary Sherman, the CEO of the RIAA, ponders the effect:

> *That's a good question and I don't know the answer. I figure it must have had an impact because basically the flood gates were opened with Napster and it was a total crisis in the industry and there was haemorrhaging, so when somebody came along with an end-to-end system that would be a legal alternative I think that the companies were far more interested in saying, 'OK;*

> *I'll try it,' rather than trying to push their own solutions. Because that was the first reaction of the companies was to try and partner with somebody for a digital service like an IBM or to develop their own music delivery systems like a subscription service through MusicNet or Pressplay. So there might have been more of a stubbornness about 'Well, we can do this ourselves' but because of the panic of what Napster unleashed there was probably more receptivity to Steve Jobs coming along and licensing, yes. (C. Sherman, personal communication June 27, 2013).*

This highlights the dynamics of the internal domain, and it is one example of many (others for example include the expectations of music retailers) of how those within the domain itself would change these expectations and configuration on account of accumulating events. Whilst new events through this time would often emerge from the lifeworld, the internal domain would shift and change on account of these events, making the outcomes that at one time were viewed as impossible, such as the licensing of music for online distribution, at a later time possible.

7.3.2 **Accumulation – relationship with lifeworld**

The accumulating state of trial and error in portable digital music players also offered those external in the lifeworld a base from which to draw for new players. The role of accumulation is such that when entering the market in 2001, Apple did not need to reinvent the portable digital music player from scratch. Instead, Apple could draw extensively from preceding designs and available component technologies.

There are many examples of components that were common to Apple's player as well as other portable digital music players. A measure of this was found in the initial consumer reaction to the announcement of the iPod. In forums such as MacRumours, some users described the iPod as a more expensive imitation of other players such as the Creative Nomad and Diamond Rio. Whilst the iPod proved ultimately to be a more effective combination of technologies, certainly Apple utilised these existing players in the design of the iPod. A prominent example is the navigation software on the iPod. Apple utilised a tree structure, where songs and albums were grouped by artist, allowing fast navigation. This design was not unique and was almost identical to software on preceding portable digital music players released by Creative. The similarity was most clearly highlighted when Creative sued Apple for patent infringement on the design, and which Apple settled out of court for $100 million (see case study section 11.3).

The accumulating available components from previous players appears important to Apple's attempt. The role of accumulation in the building of technology has also been explored and noted as important in theory. Specifically, the concept of "algorithmic compressibility"

(Tsoukas, 2005) describes how new design can utilise previous accumulation, drawing from previous work and, importantly, with those involved not needing to relearn the work that led to previous decisions, or even be particularly familiar with the history of development of that component (Tsoukas, 2005). New entrants are free to simply *utilise* the components as outcomes of previous design work to build more sophisticated solutions. Using a familiar example of an automatic teller machine, Tsoukas gives a simple explanation of this concept: "Any time, for example, you use an automatic teller machine you do not need to understand the physics and the engineering principles implicated in its design, as long as you can see the results you expect" (Tsoukas, 2005, location 1715). Tuomi similarly describes this with respect to using a computer, suggesting that those users who buy a computer do not need extensive familiarity with the design process of its internal components, but, instead, those that use computers can "simply buy a box that embeds the various competences that are needed to make computer programs operational" (Tuomi, 2002, location 580). In the case of the iPod, Apple was able to quickly draw from the existing state of understanding that had emerged from the large volume of other portable players that had been offered to the market before they entered.

An issue emerging from the case study that is not well described in these theories is that previous experimentation within the domain not only provided Apple with a compressed algorithm of technological components to use as a set of available outcomes from previous experimentation but just as significantly the previous experimentation provided Apple with a set of problems to avoid, as well as a set of problems to solve – the reverse salients (Hughes, 1983) of existing players that could be used for further advance. It was addressing problems and limitations in existing players that became the source of much of Apple's innovativeness.

For example, Apple's decision to allow the iPod to play all popular digital music formats, including MP3 was received much more successfully by consumers, compared to the previous failed effort of Sony to create their own proprietary format and restrict their player only to this format, disregarding mp3 and other popular formats. Sony, who entered the market earlier than Apple, released their first player in 1999 with a proprietary software ATRAC3, with their player not capable of playing MP3. Sony's decision to release this proprietary software came at a time when the SDMI, the large-scale group tasked to create a secure digital music standard, was at peak activity attempting to establish a secure standard that would supersede MP3. Sony, viewed as the leader in consumer electronics, and with its own record label, was heavily involved in this activity. When Sony's player was released with its proprietary software though, Sony's player failed in large measure due to this issue – it was heavily criticised by consumers, and soon SDMI itself also drew to a close, with MP3 becoming the clear dominant standard with the emergence of Napster. Apple's entry followed this activity, and by the time

Apple released the iPod, the earlier ambiguity regarding digital music formats had receded, with Apple's decision to release the iPod as a player that was capable of playing all popular audio formats, including MP3, being viewed as something that was no longer particularly controversial. It was also clear that it was what consumers wanted. Apple benefitted from the problems that Sony's previous failure had exposed.

Not only did previous accumulation work in the domain offer Apple a range of components like MP3 to simply utilise, consistent with the theory compressed algorithm, but also the wide array of available portable digital music players released prior to the iPod offered Apple compressed algorithms of problems to solve, rather than just components to use. These players offered Apple a clearer target of what to focus on in the search innovation. Rather than start from imagination and attempt to create the world's best portable digital music player, instead, Apple could start with existing players, identify limitations, and in finding advances to these limitations deliver innovation in the iPod. There are a number of tangible examples of how Apple drew from accumulating knowledge from preceding portable players in order to create the iPod, and in the original keynote announcement of the iPod, Jobs spent a great deal of effort identifying the existing problems with players as a way to frame the announcement of the iPod.

Beyond this, a prominent example of how Apple utilised existing players to create innovation is in the click wheel of the iPod. This iPod feature, one of the most recognisably unique characteristics of the iPod, was a component conceived of Apple employee Phill Schiller at an early prototype meeting at Apple. Describing the genesis of his idea for the scroll wheel, Schiller identifies that he had been using previous players from competitors and found the need to press a button hundreds of times to navigate to a particular song very frustrating. Schiller identified this as an important problem to solve, and to solve it he drew from an alternative design in the BeoCom telephone from Bang and Olufsen, which utilised a jog shuffle wheel. It appears the identification of the problem in existing players is what initiated the search for a solution.

The available accumulation of existing players on the market in this case appeared to offer Apple more than a set of technical components to utilise, but, just as significantly, a "compressed algorithm" for the problems to solve as the focus for innovation. Rather than attempting the galactic task of creating the world's best and most innovative portable music player simply by relying on imagination, instead, Apple could use the accumulated characteristics of existing players, and more pragmatically find innovative ways to improve them.

The distinction between the accumulation of technical components, in contrast to the accumulation of problems to solve within a domain, is not something that is well described in theory. Specifically, exploring the concepts of algorithmic compressibility (Tsoukas, 2005), how existing trial and error provides accumulation of problems to solve, and how these problems too represent a compressed algorithm for future experimentation represents a future research direction.

7.3.3 **Summary of question 3**

Whilst the first two questions explored the role of the lifeworld, recognising that many dramatic events emerged from the lifeworld, this third question explored the relationship between the lifeworld and the internal domain.

Addressing this question, the case study identifies that the internal domain also plays a significant role for innovation, and this concept was explored with reference to accumulation. The internal domain, frequently spurred by events emerging from the lifeworld, was dynamic and continued to change, with ongoing expectations, relationships, preferences, technological capabilities, consumer understanding, and use all shifting over time, giving the domain its own trajectory. This trajectory made events that were at one time the source of failure (such as licensing with the major labels for startups such as Napster), with further experimentation, at a later time, a key component of success (leading to the iTunes Music Store). The conditions shifted within the domain to make an outcome possible at one time and not another.

Accumulation also played a critical role in innovation. As the trajectory of the domain advanced on account of each new event, product, or experiment, the feedback was utilised for further trial and error, utilised by those within the domain, and those entering with new events from the lifeworld. In the case of Apple they were able to utilise this context of previous experimentation within the domain, which they had no involvement in, to create the iPod by utilising many common technologies, as well as utilising these existing players to identify problems to solve.

7.4 Research question 4: How do the dynamics of the lifeworld impact innovation?

The final question draws most extensively from the previous analysis chapter, where events of portable digital music players are presented as more than a chronology (as they are presented in the event history narrative) and instead reorganised through the lens of four alternative lifeworlds, in an attempt to describe how conditions of the lifeworld changed and how this impacted the likelihood and achievement of innovation for portable digital music players at different times.

The model chapter presented four alternative lifeworlds which surround a technology at different times. These are: (1) prehistory, where the lifeworld makes the technology not yet possible; (2) establishment, where the lifeworld offers enabling conditions for the creation of the technology but limited performance; (3) development, where trial and error advances the technology but reveals problems of socioeconomic alignment; and (4) innovation, where the lifeworld makes the technology an innovation, with the emergence of a dominant design with strong socioeconomic alignment. Chapter 3 describes these four lifeworlds, along with a number of markers of each lifeworld in detail, but they also are summarised in Table 7.3:

Table 7.3 Summary of the four lifeworlds

Prehistory lifeworld	The lifeworld is characterised by inadequate technology. The required component technology does not exist, making creation impossible. Despite this, imaginative description may be found.
Establishment lifeworld	The lifeworld offers enabling conditions for new creation. There is sufficient component technology available, and via exaptation and combination a new technology is established. The new technology itself will be limited in performance but demonstrates working capacity.
Development lifeworld	A large volume of trial and error emerges, with a dramatic number of entrants. These resulting products reveal problems with technology and expose various socioeconomic design criteria, from inputs such as consumers, regulations, suppliers, etc.
Innovation lifeworld	A successful design emerges to address problems of preceding designs and finds alignment across socio, political, and economic conditions. The technology proves difficult to dislodge as a successful innovation, and a large number of firm exit the market.

The lifeworld concept draws from the innovation lifecycle literature, which describes that a technology must go through a series of phases of development before innovation is achieved (Klepper, 1996; Usher, 1954). In contrast to lifecycle models though, which view this development from the perspective of the technology or the individuals involved, instead this research takes the perspective of the surrounding lifeworld, attempting to describe how the conditions surrounding an individual technology change and how this influences or determines innovation.

With respect specifically to the question of this section, “How do the dynamics of the lifeworld impact innovation?”, the case study suggests that the opportunities to create a particular technological innovation are not evenly distributed, with the surrounding state of the lifeworld presented as a major determinant of innovation performance. As the lifeworld changed, this had a direct impact on the capacity of individuals to create a technology as well as achieve innovation. The trajectory of the technology was determined in part by the trajectory of the surrounding lifeworld, and as the lifeworld changed so too did the likelihood and opportunity for innovation. The case study suggested that the successful innovation of portable digital music players can be seen to pass through four particular external environments, or lifeworlds, before being a commercial success.

Portable digital music technology began as limited imaginative descriptions with Kane Kramer in 1979 and the chippy hoax of 1981, with the prehistory lifeworld of the time constraining these technologies to imaginative description or preliminary adolescent description. By 1995 the lifeworld had changed, offering establishment conditions as a range of technologies had been created based on developments in IT technology. These technologies weren't initiated on behalf of their use in portable digital music players but instead emerged generally in the lifeworld. An example of this is the emergence of flash memory, with this new technology being used by NEC to create the Silicon Audio player prototype player (similar also to the AT&T Flashpak prototype player at a similar time). At the time, other conditions of the lifeworld made these technologies little more than isolated prototypes – the price of flash memory ($2,000 for eight to 12 song memory) made the NEC Silicon Audio a great news story about the future of music but little more than an esoteric concept with little relevance to consumers or retailers.

By 1998 the lifeworld had changed again, characterised by broad conditions that included a number of relevant technologies for digital music. The growth in the consumer internet, MP3, PC as a media tool, along with specific component characteristics such as the price of flash memory, had all emerged to give the lifeworld different characteristics. Again, many of these events were not created for the purposes of digital music players but instead represent the broader conditions in the lifeworld that became the basis from which new combinations of digital music players were created. Drawing from these conditions, the Diamond Rio and the Saehan MPMan were created in this environment, and these two devices spurred a dramatic amount of new entry and experimentation from other companies and individuals.

Post the emergence of the Diamond Rio and the Saehan MPMan, the lifeworld was particularly dynamic with related events such as peer-to-peer products in Napster and Kazaa, SDMI, and RIAA lawsuits all occurring. This is described in the development lifeworld, where the most dramatic design work of the technology occurred, but where innovation remained elusive as problems of design emerged across the socioeconomic environment (suppliers, consumers, legal, etc.). These were difficult and complex problems to address and resulted in a large range of failures. Along with the experimentation, through this time the lifeworld continued to offer new technologies. For example, the creation of the jukebox player category emerged as an alternative to flash memory players. The jukebox player market, initiated by Compaq, who created a portable player based around a laptop drive, offered an example of the continuing role of the lifeworld throughout this time. This lifeworld ends in the model chapter without the achievement of innovation; however, this lifeworld did offer continued accumulation of capacity that was soon utilised for innovation.

The final lifeworld is described as the innovation lifeworld, and this is where Apple as a single victor emerged to capitalise on previous experimentation and learning to release the iPod, iTunes, and iTunes Music Store as a combination that identified and addressed previous deficiencies to become a powerful dominant design.

A summary of the events that occurred in the four lifeworlds is described in Table 7.4.

Table 7.4 Summary of four lifeworld case study events

Prehistory lifeworld	Kane Kramer created digital drawings for a portable digital music player. However, when Kramer attempted to create the device between 1979 and 1982, he confronted impossible conditions – most of the required technologies did not yet exist, and the ones that did exist were both restrictively expensive and not widely distributed. Kramer failed despite recognising the idea of a portable digital music player, as the lifeworld did not offer capacity to create the device he wanted.
Establishment lifeworld	New technologies were available by 1995, such as flash memory, as well as smaller analog-to-digital audio converters, and file formats such as MPEG layer 2 and 3. These were utilised by NEC researchers to create the NEC Silicon portable digital music audio prototype. The device remained a prototype, out of the consumer price range, with a cost of the memory being $2,000 for eight to 12 songs. The innovation potential remained constrained and speculative. Incremental improvement trajectories continued to be important.

Development lifeworld	Flash memory prices reached new levels of affordability, and with the emergence of consumer internet, music downloading and the MP3 reached dramatic levels of popularity. In 1997, the Diamond Rio and the Saehan MPMan initiate the consumer market and spark a large volume of new entrants from consumer electronics, IT, and computer component industries. There is a dramatic amount of trial and error, with new designs building upon the first designs from Diamond and Saehan. Innovation remains elusive for those involved, as problems emerge (consumers were frustrated with user experience of the devices, issues with licensing of major label content, etc.), and expectations of the technology fluctuate. Trial and error doesn't entirely reveal an optimal design, and the achievement of innovation required something more.
Innovation lifeworld	The lifeworld continued to offer new technologies not available previously, and along with this, the accumulating understanding from the trial of previous players offers a rich range of components with higher performance compared to earlier times, along with a clearer understanding of problems. Apple uniquely recognised and seized these conditions to create the iPod as a unique combination of existing technologies, releasing this in conjunction with iTunes and then ultimately the iTunes Music Store to create a dramatic innovation. Between 2001 and 2007, Apple's strategic decisions build upon initial advantage to create a dominant design that by 2007 captures 70% of the entire portable music player market.

The lifeworld appears significant throughout all events of the case study. The creation of early ideas (Kane Kramer), the first technologies (Diamond Rio and Saehan MPMan), and later innovation (iPod) all appear to be in part reliant upon the conditions of the lifeworld that existed when they occurred. Whilst these events were the creation of particular individuals or firms, each of these events relied on conditions not controlled by the individual concerned. And significantly, as the capacity of the lifeworld was not static but instead dynamically changing as a process, it offered contrasting capacities to create innovation at different times – the lifeworld of 2001 offered enabled conditions of innovation, particularly when compared to the impossible conditions that faced Kane Kramer in 1979.

The insight is that at any given time, if the lifeworld is not rich enough, if it does not offer enough enabling technologies, resources, components, etc., the possibilities of innovation are constrained, regardless of the innovativeness of the ideas or individuals themselves. Whilst

Kane Kramer had powerful ideas for portable digital music players in 1979 with his drawings, which appear similar to the eventual iPod of 2001, the ideas of Kramer were conceived of in a lifeworld that made them an impossible technology.

In contrast by 2001, the lifeworld for portable digital music players had changed, offering Apple and all others a much richer environment that made innovation in digital music players possible and likely. The lifeworld in and of itself didn't suggest the product for innovation, but it was the act of extracting from and combining from the lifeworld that allowed Apple to create the iPod that became the success. Significantly, whilst we consider the iPod as a unique achievement of Apple, and anecdotally and in popular books, an achievement credited to the genius of Jobs, beyond this, much of the genius of Jobs and Rubinstein may be attributable not to their creation of these conditions but their *awareness* and *capacity to recognise* the wider lifeworld conditions that would allow them to create the innovation. This was something Rubinstein described in the interview – that he and Jobs only entered the portable digital music market because the conditions now offered them the components to build the type of product they wanted, explicitly noting that they had waited for these conditions, after earlier assessing these conditions and finding them lacking:

> *Anything we did at Apple we did in a heartbeat, right, we did with a sense of urgency, but we never did a product before its time. Or we tried not to. So we waited a while till the technologies would really support the kind of product we wanted to build. So we waited quite a few months, until I found the 1.8 inch hard drive, and during that time displays had matured, battery technology had matured, so it was kind of just the right moment in time to go do it. (J. Rubinstein, personal communication, July 9, 2013)*

This has implications for how we think about innovation. The capacity to achieve a particular innovation is not evenly distributed nor based entirely on individual capacity. Firms and individuals are not only competing against other firms, but they are also competing against the context in which they are placed – success or failure may be as much if not more a result of the capacities of the lifeworld they are operating in, compared to any particular competing firm or strategy that they can take. In contrast to Apple, in the lifeworld of 1979, Kane Kramer, had he all the money in the world, could not have created the iPod, as the lifeworld conditions were too limited.

A similar description was offered by Hank Barry, CEO of Napster. When describing why it was Shawn Fanning who created Napster, Barry described a "soup" that appears similar to the lifeworld concept here, where there were a range of fertile available technologies that met a fertile social context:

> *So you are in a dorm where everybody has broadband access, and you are in a mix where you've got people with big hard drives, MP3s – by the way, there's no cable TV in the dorms, so you don't have any cable TV, but you do have broadband access. So what are you going to do for fun? What are you going to do? And you don't have any money, all right, you can't buy any records. So in this mix, you have a powerful kind of soup. Bored, no money, access to broadband, access to these MP3s.. … you also had MP3 players around, so people listening to them [MP3s] but, basically to get them you have to take somebody's hard drive. You have to physically walk it over. (H. Barry, personal communication, July 10th 2013).*

This surrounding dynamic context appears different to concepts like "system" or "ecosystem" but reflects the choice of the term "lifeworld" for the description of a specific technology: At any given time there is a context, with technologies, events, people, things, not obviously or directly relevant initially to the domain in focus, but that provide powerful constraints or enabling conditions for particular events and technological innovation.

7.4.1 **Summary of question 4**

This research explored the dynamics of the lifeworld, how conditions changed over time and how this had an impact on innovation. These dynamics were captured with the description of four alternative lifeworlds. Applying this to the case study, the study found that, consistent with innovation lifecycle models, there is a clear development process for a particular innovation, with variable likelihood of innovation at different times in this process. In contrast to lifecycle models though, which view this development from the perspective of the technology or the individuals involved, instead this research takes the perspective of the surrounding lifeworld. The four alternative lifeworlds recognise that the capacity to achieve innovation is not possible at all times, and there emerge brief conditions, external to the individual, which provide a context for individual decisions and actions that can be used to create innovation. The individual is still the fundamentally important operator, but if you place Steve Jobs in the lifeworld of 1979, he would fail at creating a digital music player, much like Kane Kramer did. The genius of Jobs and others at Apple perhaps was that they wouldn't have tried in 1979, having an implicit focus on assessing the conditions and context as part of their strategy and decisions.

7.5 Chapter summary

This chapter has answered the four research questions, exploring the role of the lifeworld. There are a number of clear concepts emerging from each question, and these are summarised below.

Research question 1: This suggested that the lifeworld is important to the achievement of a specific technological innovation. Critical events to the development of portable digital players didn't emerge exclusively from the history and activity of those working on the technology already, but instead the source of new events, as well as ultimately innovation in the iPod came from those external in the surrounding lifeworld.

Research question 2: The study identifies that combination and exaptation proved critical to the development of portable digital music players, and they are concepts that describe a range of events in the case study. This chapter also presented a number of key issues of theoretical ambiguity, which present future research directions for exaptation.

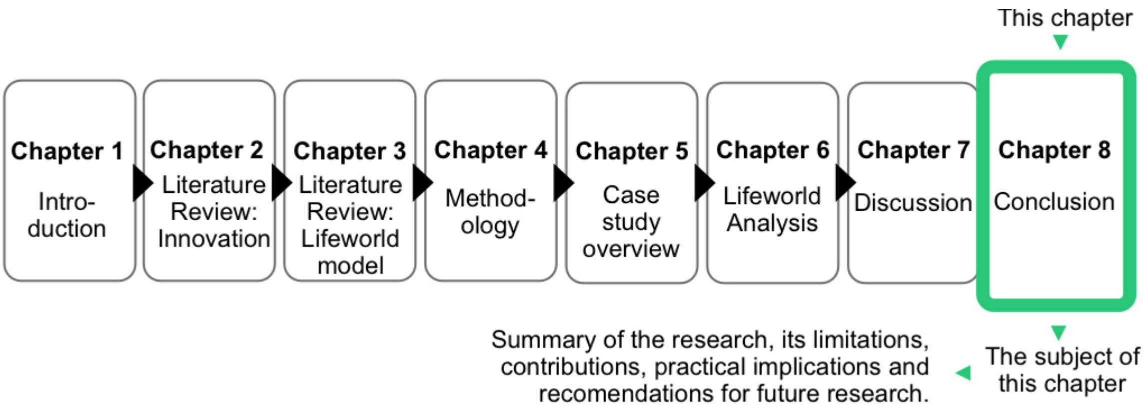
Research question 3: Whilst the above suggested the lifeworld was important, it was not the exclusive source of innovation. The internal domain was still critical, and the research discussed the role of accumulation, both in the dynamics of the internal domain as well as how those external would draw from previous accumulation within the domain. For Apple's case, they didn't need to invent everything but could draw from events and technologies that had already occurred.

Research question 4: This final question drew most extensively from the previous analysis chapter and describes the development of digital music technology as a process. It suggested that the lifeworld was dynamic over time, with the capacity to achieve innovation variable. Four alternative lifeworlds were described, exploring how conditions constrained innovation for early actors such as Kane Kramer, offered dramatic experimentation conditions with early portable players initiated by Diamond Rio and Saehan MPMan, and how post this Apple emerged in a lifeworld where innovation was possible.

This completes the discussion chapter, with the conclusion chapter offered next.

Chapter 8

Conclusion



8.0 Introduction

This concluding chapter offers a review of the research in entirety. A summary of the research questions and outcomes are provided first, followed by a discussion of the generalisability and limitations of the research and the theoretical and practical implications, along with a summary of future research directions.

8.1 Summary of the research

This research explored the role of the environment in the creation and achievement of technological innovation. The environment is presented as the concept of the lifeworld, describing the wider context surrounding a particular idea for a technology at any given time. Four lifeworlds were offered, similar to the innovation lifecycle, to describe how conditions are not static but dynamically changing, offering changing constraints and enabling conditions that impact the achievement of a particular innovation.

The lifeworld concept provides a way of seeing successful innovation as something other than unique individuals with unique ideas. Instead, an idea or an individual is dependent upon more than itself for innovation, and the context that surrounds an individual at any given time can be seen as a strong determinant of the capacity to achieve innovation. Beyond similar recognition of this concept in innovation systems literature, this research conceptualised the lifeworld as wider than a recognisable system, exploring how often important and dramatic events in the development of portable digital music players would emerge from sources (technologies, people, etc.) in the lifeworld that were previously not obviously relevant or linked to portable digital music players.

With specific reference to the case study, the study found that opportunities for innovation were not available at all times throughout the history of portable digital music players, and, significantly, through this history it appears the capacity of the lifeworld was a strong source of both constraints and later enabling conditions of innovation. Kane Kramer, attempting to create a digital music player in 1979, could have had all the money in the world and still would not have been able to create a functioning technology, much less innovation. By contrast, Apple in 2001, with little direct R&D, quickly created a combination that drew from what was available in the lifeworld, including the trial and error of previous failures, to create a product that met receptive consumers and led to dramatic worldwide innovation.

Apple utilised and seized upon available conditions in 2001 to create the iPod, drawing from technologies available in the lifeworld to create the iPod that delivered more value to users than competing products. As a mark of the significance of the lifeworld concept, the research also reveals that Apple was acutely assessing these wider conditions and the availability of technologies in its decision to enter the portable digital music player market, only engaging when it found conditions to build the product it wanted.

Related to the lifeworld concept, the research also highlighted the important role of combination and exaptation as mechanisms of creation, how things are drawn together from the lifeworld to create new technologies, along with the importance of accumulation of trial and error and socioeconomic factors that impacted the likelihood of innovation at different times.

8.2 Research process

The lifeworld concept was explored using the case study of portable digital music players. Using extensive primary and secondary data a detailed chronological event history narrative of the case was created. This is presented as the second volume and summarised in chapter 5. Following this, these events were analysed through the lens of the lifeworld model of chapter 3. This analysis is presented in chapter 6, which describes the development of portable digital music players as a process through four alternative lifeworlds. The previous discussion chapter addressed the four research questions with outcomes summarised below.

8.3 Research outcomes

This research addressed four research questions exploring the wider environment, represented as the concept of the lifeworld. The four questions of this research are:

1. How significant is the lifeworld to events and innovation in the case study?
2. How are combination and exaptation relevant in the development of innovation?
3. What is the relationship between the internal domain and the external lifeworld?
4. How do the dynamics of the lifeworld impact innovation?

Summarising the discussion chapter, the research questions were answered as follows:

1. *How significant is the lifeworld to events and innovation in the case study?*

The case study suggested that the lifeworld is important. Prominent events in the case study were not exclusively dependent on those within the domain or the preceding history of digital music or digital music players, but instead new events emerged from companies, people and technologies more broadly from the lifeworld. These external technologies had their own preceding trajectory in the lifeworld, that were connected to the domain to create dramatic events.

The most prominent example of this is Apple itself. The event history narrative described many prominent and important events in the development of portable digital music players prior to 2001. Yet, despite the large volume of events, prior to their engagement with the release of iTunes and the iPod in 2001, Apple were not significantly involved, and did not play a prominent role in development. If the narrative had stopped prior to 2001, it would have missed the defining innovation from Apple.

Further highlighting the role of the lifeworld, the discussion chapter also described the lifeworld with reference to the constant state of uncertainty that characterised development for all involved. New events such as Napster, Kazaa, iTunes, and the iPod constantly emerged as shocks to those within the domain, similar to those described by Van de Ven et al. (1999), where assessment and analysis did not account for these coming events prospectively. Discussing this with reference to theory, the discussion chapter utilised the time series trap

(McMullen & Dimov, 2013) as particularly useful to promote how the emergence of new external events requires the reconfiguration of the internal environment.

2. *How is combination and exaptation relevant in the development of innovation?*

The study confirms and impresses the importance of combination and exaptation as concepts that describe something significant to new technological creation and innovation. Whilst there were many examples, most significantly again, the iPod is a powerful example of the role of combination and exaptation in new technological creation. In the discussion chapter (drawing from case study section 10.5), the iPod was explored and described in detail as a combination. The primary interview with Jon Rubinstein, who led the iPod development at Apple, also highlighted how Apple were cognisant of combination as the strategy for creation. A number of times throughout the interview, Rubinstein stressed that the iPod was a combination of available technologies, and along with giving detail of the combination of iPod, Rubinstein also offered wider advice regarding new technological creation: "*It's always the combination of the technology".*

With the importance of exaptation and combination in theory and the case study, the discussion chapter further explored these concepts, identifying a number of theoretical ambiguities emerging from the case study. Summarising these again, they are:

- With respect to technology, the difference between combination and exaptation is not clear. The discussion chapter described the difference between biological exaptation and technological exaptation, highlighting that a technological combination can also include exaptation, as well as the concept of multiple adjacent developments, where the combination can be of independent technologies or ideas. This made identifying exaptation events in contrast to combination events as distinct, particularly difficult with this issue and one that can be refined further in theory.

- The role of incremental improvement in existing technologies appears critical to creating windows of opportunity for exaptation and combination. The trajectory of existing technologies was viewed as important, and often it was a shift in characteristic of familiar technologies rather than the emergence of a dramatically new technology that made new combinations possible.

- Finally, the case study presented examples of exaptation that are not well described in theory – both exaptation of concepts rather than just technologies, and also examples of failed exaptation where exaptation did not lead to significant innovation. These types of exaptation are not well described in theory, and exploring these issues suggest a possible avenue of advance for theory, with particular opportunity to articulate combination and exaptation as mechanisms of creation rather than exclusively mechanisms of innovation.

With the importance of combination and exaptation emerging from the research, these points are viewed as significant future theoretical directions that will be explored in future research endeavour.

3. *What is the relationship between the internal domain and the external lifeworld?*

The third question explored the relationship between the internal domain and the external lifeworld. Whilst the first two questions explored the role of the lifeworld, this third question recognised that the domain itself also had a critical role in the achievement of innovation, and the external lifeworld was not the source of innovation in and of itself. Whilst new events would often emerge from actors in the broader lifeworld, these new events too would interact with and draw from the existing domain.

The discussion chapter described the interaction between the internal domain and the lifeworld in two concepts. First, it described the role of accumulation. The internal domain was dynamic and would respond to events, making different outcomes possible at different times. Second, and extending this, the theory of compressed algorithms (Langley, Smallman, Tsoukas & Ven de Ven, 2013) was used to describe how those external in the lifeworld would draw from the accumulation that had occurred in the domain. Rather than having to create concepts from scratch, new events could build on previous experimentation. Drawing from the case study, the discussion chapter highlighted how previous experimentation with portable digital music players not only provided Apple with components to use that they didn't need to reinvent (MP3, downloading, CD burning, technological components such as hard drive, etc.) but just as significantly, previous portable music players released to the market offered Apple a set of problems to solve – the limitations (or reverse salients; Hughes, 1983) with existing players presented a compressed algorithm for Apple, where addressing problems and limitations of existing players was the source of innovation, such as the frustration of clicking through menus (leading to the creation of the scroll wheel), or that some players required proprietary audio formats (where Apple instead made the iPod capable of playing a wide range of formats including MP3). It was while addressing problems and limitations in existing players that Apple created a player with a much-improved value for consumers.

4. How do the dynamics of the lifeworld impact innovation?

The final question of the research investigated the lifeworld as a process. It presented four lifeworld stages, exploring how conditions of portable digital music players changed over time, and how dynamics of the lifeworld impacted the capacity to create innovation. The case study demonstrated that the likelihood of innovation in portable digital music players wasn't evenly distributed, but instead, that the lifeworld offered strong constraints at some times and enabling conditions at others. The four lifeworlds of portable digital music players were described as follows.

Prehistory lifeworld (pre–1994): There were a number of early imaginative descriptions of portable digital music players, prior to it being possible to create a working technology. The most notable attempt was that of Kane Kramer in 1979 who drew his concept IXI Player, and established a company in an attempt to create the device. Despite his drawings appearing similar to the eventual look of the iPod, and with Kramer able to create audio limiting patents on digital audio, Kramer failed. The study explored this as a failure in part due to the characteristics of the lifeworld at the time. Kramer faced extreme limitations of technology, with the lifeworld not yet having sufficient availability of required technology. In a recent interview, Kramer himself also noted that the limitations extended beyond the obvious technology, with consumers not comfortable with the idea, acknowledging that even if he could have created the player in 1979, it would be of no use as there were not yet any digital music files to play on the device, with the majority of studios still recording to magnetic tape.

Establishment lifeworld (1994–1997): The dynamically changing lifeworld continued to accumulate capacity, and in 1994 NEC announced a prototype portable digital music player. Drawing from technologies available at the time, particularly flash memory, and audio format MPEG layer 2, NEC announced the new prototype player. The technologies of the time also limited the device to only ever being a prototype: The cost of the memory was $2000 for the eight to 12 song prototype, resulting in it being far outside the consumer range, with NEC deciding not to pursue the player.

Development lifeworld (1997–2001): These years are significant years in the development of portable digital music players, and digital music more generally. In 1997 and 1998 the first portable music players in the Diamond Rio and Saehan MPMan were released to the public. Soon, this initiated a large volume of new entrants, as companies released players based around similar designs. The large volume of new players created a significant process of trial and error as preferences of the lifeworld were revealed, with many elements (support industries such as the recording industry, legal precedent) offering favour to the competing technology of compact disc. The technology of portable players was still immature relative to what would soon be possible, and consumer use of these players revealed frustrations, such as the constraints of memory (cost/capacity) and battery life. At the same time as this experimentation in portable players, a number of dramatic events occurred in digital music more generally. The availability of PCs with sound cards, fast enough processors, and affordable internet, along with CD burners led to events such as mp3.com, Napster, Kazaa, and music software such as MusicMatch. This time was characterised by a large amount of intrigue, experimentation, description and analysis of events and forecasts, as well as failure of many products. The development lifeworld ends with lasting innovation still elusive, but with the large volume of activity offering accumulating conditions that would soon be capitalised on.

Innovation lifeworld (2001–2008): Apple released the iPod in 2001, and it grew to become a powerful dominant design. With iTunes also released in 2001, the iPod initially found success relative to the other players available in the market. By 2004, Apple had bifurcated the iPod from a single product to a product range, established the iTunes Music Store, and released iTunes on the Windows platform. With these developments, iPod moved from initial success in the product niche, to powerful worldwide phenomenon, with Apple capitalising and creating the shift of portable digital music players from niche to mass market product.

Whilst the iPod is credited to Apple as a unique achievement, the lifeworld presented Apple opportunities for innovation that were not available at previous times, such that it is possible to say that Apple would not have succeeded in creating the iPod if they had tried at any time previous to 2001. For example, the lifeworld offered new exaptation opportunities to Apple in 2001, with Apple utilising a new 1.8 inch prototype laptop hard drive from Toshiba to create the iPod that wasn't previously available. The availability of these conditions was outside the control of Apple, and the study finds that the enabling conditions of the lifeworld were a large contributor to Apple's success.

However, the study also found that Apple was significant in identifying and creating these conditions. The iPod was not an obvious exclusive extension of previous players, but Apple created a unique combination drawing from available technologies and understanding in the domain, as well as their own unique sensibilities and experience. This created a unique product that delivered superior value to consumers. Whilst the lifeworld offered conditions that made dramatic innovation possible in 2001 compared to previous or later times, the study also found that Apple's performance was unique with respect to recognising and seizing these conditions

The lifeworld was dynamic, and offered varying capacity to achieve innovation at different times. The concept appears to have merit, and the exploration of the wider environment in which ideas and technologies are conceived useful. The limitations of the research, and the lifeworld concept will now be discussed.

8.4 Limitations of the research

The lifeworld model was an attempt to describe something inherently difficult: how the things surrounding an idea for a technology (events, other technologies, individuals, etc.), not initially or at times obviously relevant to it, can impact its development and performance as an innovation. This is an intrinsically difficult research phenomenon to explore. Adding to the complexity, the research also acknowledged the importance of viewing innovation as a process, and attempted to explore this lifeworld as a process – how it changed over time, and how this leads to differences between conditions that enable and constrain innovation.

Whilst ultimately the research achieves the goal of exploring this lifeworld and offers some useful theoretical and practical implications, there are a number of limitations that will be discussed. These relate to the lifeworld concept, methodological decisions, and also the aims and criteria of this research as PhD research. These will each be discussed below.

8.4.1 **Limitations of the lifeworld concept**

One limitation and risk of this research is that the lifeworld concept may appear contrived and viewed simply as an idiosyncratic collection of ideas, which then through selective case study application have been artificially confirmed as significant.

This is not the intent or outcome of the research, and the researcher prioritised not a set of ideas, but instead the exploration process of existing theory as well as the events of the case.

In presenting the lifeworld concept, it draws extensively from the lifecycle theory and the prominent process theory of technology. The model is framed with the term "lifeworld", due to their appearing no entirely suitable terminology to describe the context for individual technology, despite there being an abundance of words that are close in meaning – words such as ecosystem, system, context all appear useful words but were not viewed as entirely effective in contrast to lifeworld. Beneath the term "lifeworld", all of the model, as too the preceding literature review that framed the importance of exploring it, are based on existing useful theories of innovation and particularly technological innovation.

Beyond the theory, with respect to the case, the researcher has not been selective in the construction of the case to confirm the importance of concepts. Instead, the researcher presented the case study first as a detailed *chronology* of events. The event history narrative was constructed in detail independent of any theory, and the vastness of the event history narrative presented as a second volume is a large measure of the researcher's commitment to this task. An important motivator for the exploration to begin was a decision to respond to the historical genius model of innovation, which through selectivity of case material often presents events as outcomes of individuals exclusively (e.g., literature review discussion on individual genius). Whilst it would have been much faster to complete this research by simply running a data search related to Steve Jobs, instead this research undertook a more detailed process of documenting and exploring the significant amount of failures, incidental events, and accumulating context that preceded the iPod just as much as the success of the iPod itself.

For these reasons, whilst the lifeworld concept may be critiqued because of its lack of uniqueness to this research, the aim of this model, to explore the wider environment that constrains and impacts innovation, appears important. And rather than the conclusion of this research being that the lifeworld model is an effective way to describe innovation, instead, the ambition of it is pragmatic – when thinking about innovation, issues like combination, exaptation, and the lifeworld are things that should be considered.

8.4.2 **Process research complexities and limitations**

This research is process research, with four alternative lifeworlds to describe how conditions change over time. This is a limitation of the research, and there are a number of issues related to the recognition of four alternative lifeworlds that must be addressed.

Offering four alternative lifeworlds is an attempt to describe the lifeworld as a process, how external conditions change over time and how this impacts the achievement of a particular technological innovation. Process research like this has its own epistemological foundation that is inherently complex as discussed in the methodology chapter. It starts with recognition that everything is in flux, and using methodological tools attempts to explore, recognise, and describe the temporal process of change that leads to events.

Phase models, which describe process by way of a series of markers for particular stages, are a common and accepted technique in process research (see the table in Methodology) and innovation research, and have received empirical support (Stubbart & Knight, 2006). However, phase models receive criticism on account of the risk of oversimplification and misrepresentation they bring to complex phenomena (Van Lente, Hekkert, Smits & van Waveren, 2003, p. 260). This criticism of phase models is that they, like the bed of Procrustes, make an overwhelmingly complex phenomenon fit a rigidly defined standard (Taleb 2016), potentially dangerously misrepresenting both the phenomenon as well as level of possible understanding of the phenomenon.

This is a risk of reductionism, and one that is common of phase models, including this research. The use of four alternative lifeworlds similar to phases of innovation lifecycle models is acknowledged as this limitation. Whilst it is drawn from theory, the lifeworld concept may not have the capacity to fully represent the complex phenomena or process that it is attempting to describe. In response, the perspective of the researcher is that the case study promoted a particular perspective on this – there is a need for strong conviction with respect viewing innovation as a process, but for this conviction to be weakly held with respect to the ultimate ability of the four lifeworlds to capture this process in completeness. There may be more effective ways to articulate this concept, which offer greater clarity of process, and that capture more detail offering more value.

Related to this, another limitation is the number of lifeworlds recognised. Much like the criticism of innovation phase models (Pinch, 2010), the selection of four lifeworlds is acknowledged to be somewhat arbitrary based on the perspective of the process. The model presented four alternative lifeworlds to reflect the different phases of innovation lifecycle models such as Usher's (1954). The description of four lifeworlds was drawn from theory, but ultimately all process models that attempt to describe a lifecycle make decisions about how to articulate that process in stages, and the result is that there is no clear or obvious 'standard' number of phases. Abernathy and Utterback (1978), for example, describe a new technological innovation development in three phases: A "fluid phase", "transition phase", and a "specific phase". Perez (2001) describes the process of how technologies become embedded in the economy as a four-phase process: Phase one is "irruption", phase two "frenzy", phase three "synergy", and phase four "maturity". Rogers (1983) identifies five different categories of consumers in the diffusion process: Innovators, early adopters, early majority, late majority, and laggards. Ogburn (1950) describes innovation from the perspective of the individual as a four-phase process: (1) Invention, (2) accumulation, (3) diffusion, and (4) adjustment (Ogburn, 1950, p. 393). This is similar to Usher (1954), who also offers a four-phase model, including (1) perception of an incomplete problem, (2) setting the stage, (3) act of insight, and (4) critical revision and full mastery. The number of phases in each model appears arbitrary when viewed as a collective group of theory. Some models offer three phases (Abernathy, & Utterback, 1978; Geels, 2002), others four (Christensen, 1997; Meijer, Hekkert, Faber & Smits, 2006, p. 220; Perez, 2007, 2010; Usher, 1954), others five or more (Rogers, 1983; Suárez, 2004). Whilst the presentation of these phases in each model is well justified, there does not appear to be any consistency with respect to the number of phases or agreement with respect to how many phases is useful.

These differences can perhaps be attributed to the difference in focus of each theory. Similar to what Giddens (1984) described in his theory of structuration in sociology, differences in the unit of analysis make some of these theories cover similar concepts in widely differing ways. Some theories provide wide coverage of the process of technological change from inception to maturity, whereas others only focus on a specific stage of the process. For example, Perez's

(2004) theory of technological economic paradigms provides description from a gestation phase through to technological maturity. Others too such as the linear model of innovation, technological paradigm (Dosi, 1983), technological regime/trajectory (Nelson & Winter, 1982), and the multilevel perspective (Geels, 2002; Rip & Kemp, 1998) similarly describe the process from initiation to maturity. In contrast some theories describe process by avoiding phases, and by almost exclusively focusing on a particular segment of the process. For example, Arthur (1989) focuses entirely on technological lock which creates windows of entry, and Anderson and Tushman (1990) focus on market-based assets that have an effect closer to maturity states. This multitude of different perspectives on process don't reduce the validity of viewing things as a process, but instead highlight the difficulty of the research.

Reflecting more specifically on this issue for this research, the lack of standardised number of phases, as well as the criticism related to the use of phases appears related to the complexity of describing process, and the need to rely upon reductionism as an important tool for this description, rather than being a point of critique regarding validity. Capturing and describing process in motion is particularly difficult, and as Dennett (1996) suggests, reductionism is valid and important as long as researchers do not over represent the descriptive capacity of the theory.

8.4.3 **Methodological limitations**

Along with the above reflections on the nature of the lifeworld concept, there are a number of methodological limitations that will be discussed below with respect to the case study of portable digital music players.

8.4.3.1 Generalisability

This research of portable digital music players is a single in-depth case study. Whilst this is a popular methodology, and one which has produced a number of seminal references in the innovation literature (e.g., Christensen, 1997; Constant, 1980; David, 1980; Gilfillan, 1935; Hughes, 1983; Van de Ven et al. 1999), the single case methodology is recognised methodologically as one that comes with risks of limited generalisability (Yin, 2013).

As discussed in the methodology section, the difficulty of generalisability is an issue that affects all innovation research due to the innate characteristic of each innovation being unique in some way, and it is suggested that this in part is why detailed single case studies have been so useful in the innovation literature, rather than the search for the single grand abstraction that describes all innovation. However, a noted limitation is that the conclusions emerge from this case study alone. This research is specific in what it describes, and its utility to other cases is something that will take specific analysis beyond the generalisable contributions noted below.

8.4.3.2 Data

A strength of this research is the amount of reliable data that was used. The Internet Archive was a powerful data source, which has relevance for future innovation research endeavours. The sheer volume of data, though, was laborious, and future research may also look to more advanced methodological tools such as concept mapping and software tools that offer quantitative insight.

8.4.3.3 PhD research

The final methodological limitation is the purpose of the research itself. This research is a PhD thesis and was constructed under the limitations and constraints of the thesis format and the PhD process itself. Often unlike significant research for journal publication, I constructed this thesis by myself, outside of a community of researchers in the theoretical domain of technological innovation. If there are erroneous interpretations of existing theory, then these should be viewed as naivety as opposed to arrogance. This research represents my own apprenticeship in both the theory as well as detailed case study methodology.

8.5 Contribution to knowledge

This research has explored the role of the environment, recognised as the concept of the lifeworld. It has identified that the lifeworld in which an idea is placed is critical to the achievement of innovation. Below is a summary of both the practical and theoretical contributions to knowledge, as well as future research directives.

8.5.1 **Practical implications**

In the introduction, this research began by describing the practical problem that was to be explored: Below the surface of iPod’s success, there were a large volume of other entrepreneurs and individuals who conceived of and pursued the same ideas prior to Apple. How was it that Apple succeeded when there were so many talented entrepreneurs and industry experts exploring these similar ideas for digital music players and failed? These individuals and companies had many of the same ideas that Apple used to become innovative, and they had them long before Apple did. So, should Kane Kramer, or Michael Robertson, or the creators of the Diamond Rio, or any other preceding entrepreneurs or companies prior to Apple that explored the same ideas be viewed as the innovators?

With the research complete, it seems futile to argue that Apple weren't the clear innovators in portable digital music players and digital music distribution more generally. They completely dominated the market, delivering a product that outperformed anything previous to it, and all portable digital music players after it, to be only superseded by another of their own products in the iPhone. Apple should be viewed, in the popular sense they already are, as the great innovators of the domain and the era more generally.

The study does suggest though that there is need to qualify the attribution of this success to the singular genius of Jobs. The perspective of Jobs as the heroic genius who had unique ideas others didn't appears wrong, and disregards the significant contribution and work of those who preceded Apple. There is clear evidence, promoted even by Jon Rubinstein, that Apple relied heavily on the available conditions of 2001, including many of the previous technologies, ideas and failures that preceded their engagement.

Instead of attributing the success of Apple to unique ideas, their achievement appears dependent upon the particular context of the time. Using combination to draw from the environment, Apple both created and realised conditions that made *innovation* possible in portable digital music players in 2001 compared to previous times when these conditions were not yet possible. Recognising and seizing upon these conditions appears the genius of Jobs, Rubinstein and others at Apple, who describe waiting for these conditions as a deliberate strategy.

This awareness of the context, how dynamic conditions had changed to offer potential for innovation in 2001 not possible at previous times, appears critical to the achievement of innovation for Apple and has implication for others too. The lifeworld model demonstrated that the idea of a portable digital music player had a long history, with many who attempted to bring it to life as an innovation. Through this history, almost all others faced constraints that made innovation in portable digital music players impossible. In contrast, Apple engaged at a time when the conditions enabled innovation, and with little direct R&D Apple were able to capitalise on these primed conditions to create powerful innovation.

The lifeworld concept demonstrated that the constraints and enabling conditions are external to those who try, leading to the implication that if Apple had attempted to create the iPod in 1969 like Kramer's failed IXI player, or in 1994 like the Silicon Audio player from NEC researchers, or in 1997 like Saehan or Diamond, Apple too in all of these contexts would have failed. The genius of Apple, under the leadership of Jobs and Rubinstein, was that they wouldn't have tried to create the iPod at these earlier times.

8.5.2 Theoretical implications and future research

Whilst the use of the term “lifeworld” may remain idiosyncratic to this study, the concept of what it is attempting to describe appears important – that the conditions surrounding an idea for a technology at times present extreme constraints to the achievement of innovation, and at other times make the same innovation likely. It is something different to an innovation system or an ecosystem, and the lifeworld concept along with the case study explores how events would often emerge not from previous direct activity of those working on the technology of portable digital music players, but instead the interaction of wider technologies that existed more generally in the lifeworld. Important technologies that were critical to the development of portable digital music players often had a history of being applied to other domains with initially at least no clear or obvious relevance to the domain of portable digital music players. This highlights the importance of the lifeworld concept and it is this which the concept attempts to illuminate.

The model also describes the lifeworld as a process. How, like innovation lifecycle models, conditions are dynamic, creating temporal differences in the capacity to create technology as well as innovation. The prehistory lifeworld described conditions which did not allow for the creation of the technology. Establishment and development lifeworlds provided conditions that enabled the creation of portable digital music player technology, but did not allow for the creation of innovation. Innovation lifeworld, offered powerful enabling conditions for innovation, resulting in the emergence of a dominant design. Exploring these ideas with reference to answering the research questions also brought with it a range of insights in the discussion chapter, which highlighted the following theoretical issues:

- Uncertainty is a fundamental characteristic of new technological development. With reference to the time sequence trap, uncertainty was explored as a characteristic that highlighted the importance of the lifeworld, how new events would emerge from external sources, rather than the existing narrative exclusively.

- Combination and exaptation are important mechanisms of creation. The discussion chapter provided a number of directives with respect to future research exploration of these concepts.

- Trial and error (represented as the large volume of new portable digital music player products preceding Apple) was a critical process by which socioeconomic criteria were exposed.

- Accumulation of selection feedback offered a basis for further experimentation. With reference to the concept of compressed algorithm, accumulation provided Apple not only with a range of components to use, but also a range of problems to solve.

- Viewing innovation as a process has merit, and the case study provides strong support to the recognition that capacity to achieve a particular innovation is not absolute, but relative to the context and conditions of the lifeworld at any given stage.

Along with the concept of the lifeworld itself, these themes represent a range of theoretical implications and future research directions which the researcher intends to explore.

8.6 Chapter Summary

This chapter summarised the research, giving an overview of the research process, presenting the findings, discussing the limitations, and finally identifying the contribution to knowledge both from theoretical and practical perspectives, as well as offering future research implications.

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