Technology Strategies for Transitioning from Products to Services

by

Erdem Yılmaz

M.S. Electrical Engineering (2008)
University of Massachusetts, Dartmouth

B.S. Electronics and Communication Engineering (2005)
Technical University of Yıldız

Submitted to the System Design and Management Program
in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Engineering and Management

at the

Massachusetts Institute of Technology

June 2017

© Erdem Yılmaz
All rights reserved

The author hereby grants to MIT permission to reproduce and to distribute publicly paper and electronic copies of this thesis document in whole or in part in any medium now known or hereafter created.

Signature redacted

Erdem Yılmaz
System Design and Management Program
May 12, 2017

Signature redacted

James M. Utterback
Thesis Supervisor
David J. McGrath jr (1959) Professor of Management and Innovation and Professor of Engineering Systems

Signature redacted

Joan Rubin
Executive Director, System Design & Management Program
Technology Strategies for Transitioning from Products to Services
by
Erdem Yılmaz

Submitted to the System Design & Management Program
on May 12, 2017 in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Engineering & Management

Abstract

Research in this thesis is motivated by product transitions, historically first from physical products to virtual products and lately from virtual products to services. The recorded music industry was focused on understanding the dynamics of transitions from one generation of use to another. The recorded music industry was selected to study as it is one of the most dynamic and rapidly changing industries. Results of the most recent transition in the industry are deeply investigated.

Utilizing numerical computing techniques, and mathematical models inspired by ecology sciences, a software package was created to analyze technology transitions. The software package was used to analyze the music industry. Accuracy of the technique was demonstrated and the model parameters were investigated and discussed.

Effective strategies for the service transition are discussed. Limitations and characteristics of the transition are further investigated. Both new and existing firms from other industries who adapted well into such transitions are examined with the purpose of understanding critical points in their strategies that allowed them to execute such transitions successfully. Architectures of modern systems that reflect on the transition, such as product as a service are discussed. A few examples from the industry in which some of the critical components are transitioning to service model that resembles the ones in the music industry are given.

Thesis Supervisor: James M. Utterback
Title: David J. McGrath Jr (1959) Professor of Management and Innovation and Professor of Engineering Systems
This page is intentionally left blank
Acknowledgements

First, I would like to thank my advisor Professor Jim Utterback for all of the incredible things he taught me and for his generous support of my research. I’m grateful for the opportunity to have worked with a person of such a high intellect. Prof. Utterback has always been available for me and his mentorship was the highlight of my experience at MIT. Thanks for being an excellent role model, teaching me how to focus and being the best mentor, Professor! I’m looking forward to working with you on new ideas and projects in the future.

I could not be where I am today without my family. My parents have always been extraordinarily supportive of me. I’d like to express my sincere gratitude to my father Mehmet, an avid researcher, to my mother Aliye, whose warmth and energy radiate all the way from Istanbul to Boston, and to my brother Ercan, our artist and businessman. Thank you!

I would next like to also thank the SDM core teaching team: Prof. Oli de Weck, Dr. Bryan Moser, and Dr. Bruce Cameron, and Andrew, John, Nissia, and Shawn for all of the hard work that went into preparing the core class. I would like to acknowledge Professor Nicholas Ashford, for teaching me how important sustainability is, Bill Aulet for an excellent class in entrepreneurship, and Professor Feng Zhu from Harvard Business School for further encouraging my research on technology and innovation.

Big thanks to my wonderful friends from MIT and Harvard who enriched my journey and made incredible contributions to my experience in the last two years. MIT expanded my limits and I couldn’t have gone on without your friendship and support. Thank you!

Last but not least, I cannot thank enough my dear wife and friend Özge for her support, kindness, encouragement, and unconditional love, from the first day to today. You are the best thing that has ever happened to me. Thank you, I love you!
This page is intentionally left blank
# Table of Contents

Chapter 1 - Introduction .............................................................................................................11  
Summary and Background ........................................................................................................11  
Motivation ...............................................................................................................................13  
Basic Definitions ....................................................................................................................14  
Research Questions ...............................................................................................................15  
Acknowledgment ..................................................................................................................16  

Chapter 2 - From Products to Services in the Music Industry ..................................................17  
Capturing Value from Recorded Music ....................................................................................18  
Scope of This Research in the Music Industry .......................................................................19  
Phonograph and Redefinition of the Music Publishing Industry ............................................20  
Following Product to Product Transitions ............................................................................23  
   Gramophone and 78 RPM ....................................................................................................23  
   78 RPM and LP ..................................................................................................................24  
   LP to Audio Cassette ..........................................................................................................24  
   Audio Cassette to Compact Disc ......................................................................................25  
Transition from Physical Products to Virtual Products .........................................................26  
Metrics for Transitions ...........................................................................................................29  
   Cost per minute ................................................................................................................29  
   Portability .........................................................................................................................29  
Transition from Virtual Products to Streaming Services ......................................................31  
   Streaming Failures: MusicNet and PressPlay ..................................................................31  
   Streaming Success: Spotify .............................................................................................31  
Dimensions Changed with Streaming ...................................................................................34  
Major Changes in Stakeholders with Streaming ....................................................................35  
   Artists ...............................................................................................................................35  
   Unexpected New Stakeholders .........................................................................................36  

Chapter 3: Analysis of the Transitions in the Music Industry with Lotka-Volterra Equations ..39  
Ecology and Business Modeling ............................................................................................39  
Modified Lotka-Volterra Equation to Analyze Interactions Among Technologies ...............41  
   Generalization, Solution, and Analysis of the Modified Lotka-Volterra Equation ..........42  
Analysis Technique ..............................................................................................................44  
   Trust Region Reflective Algorithm and Genetic Algorithm ............................................44  
   Methodology to Analyze Music Industry Data ................................................................46  
Analysis Results ..................................................................................................................49  
   Analysis of Phase – 1 .......................................................................................................49  
   Analysis of Phase – 2 .......................................................................................................53  
   Analysis of Phase – 3 .......................................................................................................55  
   Analysis of Phase – 4 .......................................................................................................56  
Conclusions of the Analysis ..................................................................................................58  

Chapter 4 Conclusions and Discussions ...................................................................................59  
Learnings from the Music Industry .........................................................................................59  
Examination of the Model ......................................................................................................61  
Other Content Based Industries ............................................................................................61  
   Home Video Industry – A hybrid transition ..................................................................61
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Book Publishing Industry - Limitations of the Transition</td>
<td>64</td>
</tr>
<tr>
<td>Examples from Outside of the Content Based Industries</td>
<td>66</td>
</tr>
<tr>
<td>Service Transition on Critical Supplies – HP Instant Ink</td>
<td>66</td>
</tr>
<tr>
<td>Other Examples of the Model</td>
<td>67</td>
</tr>
<tr>
<td>Software Industry – Root of the Transition</td>
<td>68</td>
</tr>
<tr>
<td>Discussions</td>
<td>68</td>
</tr>
<tr>
<td>Discussion on Characteristics of the Service Model</td>
<td>68</td>
</tr>
<tr>
<td>Discussion on Technology Strategy</td>
<td>69</td>
</tr>
<tr>
<td>Discussion on Pricing</td>
<td>70</td>
</tr>
<tr>
<td>Conclusions</td>
<td>72</td>
</tr>
<tr>
<td>References</td>
<td>77</td>
</tr>
<tr>
<td>APPENDIX</td>
<td>80</td>
</tr>
<tr>
<td>Matlab Codes</td>
<td>80</td>
</tr>
<tr>
<td>Instructions</td>
<td>80</td>
</tr>
</tbody>
</table>
List of Figures

Figure 1 Inflation Adjusted US Recorded Music Revenues by Format .................................................. 17
Figure 2 Original Edison Tin Foil Phonograph .................................................................................... 22
Figure 3 Dimensions of the Transition from Sheet Music to Phonograph ............................................. 22
Figure 4 Dimensions of the Transition from Phonograph Cylinders to 78 rpm Record ....................... 23
Figure 5 Dimensions of the Transition from LP to Compact Cassette .................................................. 25
Figure 6 Dimensions of the Transition from Audio Cassette to Compact Disc ...................................... 26
Figure 7 Apple iPod First Generation .................................................................................................. 28
Figure 8 Dimensions of the Transition from Physical Products to Virtual Products ............................ 28
Figure 9 Cost of Listening to One Minute of Song from 1973 to 2015 in Today’s Dollars ................. 29
Figure 10 Physical Volume Comparison of Record Players ..................................................................... 30
Figure 11 Volume Comparison of Record mediums ............................................................................. 30
Figure 12 Spotify Membership Types ................................................................................................. 32
Figure 13 Number of Paid Spotify Subscribers Worldwide 2010 – 2016 ............................................ 33
Figure 14 LP/Vinyl Album Sales in the USA ......................................................................................... 37
Figure 15 Framework for interactions among technologies ................................................................. 42
Figure 16 Optimization approach ......................................................................................................... 46
Figure 17 Phases of the recorded music industry .................................................................................. 47
Figure 18 Phase-1 Analysis and Predictions ......................................................................................... 50
Figure 19 Phase-1 Analysis with Constraining Positive Self-coupling ................................................ 51
Figure 20 Early Interactions in Phase-1 ................................................................................................. 52
Figure 21 Phase-2 Analysis .................................................................................................................. 53
Figure 22 How early LV Can Detect an Emergence ............................................................................ 55
Figure 23 Phase-3 Analysis and Prediction .......................................................................................... 56
Figure 24 Phase-4 Analysis and Prediction .......................................................................................... 58
Figure 25 Number of Netflix Subscribers in Millions ........................................................................ 63
Figure 26 Distribution of Movie and TV Rental Market Revenue in the United States from 2012 to 2016 ......................................................................................................................... 63
Figure 27 Distribution of Reading Preferences in U.S. Adults ............................................................... 65
Figure 28 Instant Ink Subscription Types and Pricing ........................................................................ 66
Figure 29 Instant Ink Service System .................................................................................................. 67
List of Tables

Table 1 Stakeholders in the Music Industry ......................................................... 19
Table 2 Main Activities in the Music Industry ..................................................... 20
Table 3 List of Products Used in the Study .......................................................... 30
Table 4 List of Spotify Partnerships ..................................................................... 34
Table 5 Music Format and Required Sales for a Minimum Monthly Wage .......... 35
Table 6 LV Coefficient visualization format ......................................................... 48
Table 7 Coefficient Parameter Details ................................................................. 48
Table 8 Model Parameters Phase-1 ..................................................................... 49
Table 9 Model Parameters for Early Interactions in Phase-1 ................................. 52
Table 10 Model Parameters Phase-2 .................................................................... 53
Table 11 Model Parameters Phase-3 .................................................................... 55
Table 12 Model Parameters Phase-4 .................................................................... 57
Chapter 1 - Introduction

Summary and Background

Today, consumers can listen to virtually any song for free by using one of the many legal online services. Thanks to companies offering music streaming services such as Spotify, Sound Cloud, Deezer, Rdio, Pandora, Apple Music, Grooveshark, and others, music is more available and accessible than it has ever been. Have there been signals in the history of the recorded music industry indicating the emergence of streaming services? What metrics motivated the recorded music industry to experience a shift in the market demand - a transition - from one storage technology to another in the past? Are these metrics still relevant today? Are there other industries that might experience a similar transition in services?

This thesis presents the findings from research focused on the recorded music industry to understand the dynamics of transitions from one generation of use to another. The recorded music industry was selected for this study as it is one of the most rapidly evolving industries. Like any industry, music has gone through many rounds of technological change. For example, digital technologies replaced analog technologies, changing the architecture of audio equipment; while developments in mobile technologies created a shift from computers to tablets and smartphones, which allowed consumers to listen to music from their phones; and advanced electronics reduced the noise in amplifiers improving home audio systems, etc. Many such examples of the technological impact on the music industry can be given. The research in this thesis focuses on the technologies functional in storing recorded music data such as Vinyl, CD, MP3, etc.

In the following chapter, a brief history of music recording is provided, with an emphasis on the major technologies with the largest impact in the industry. Transitions for the market demand in physical products, such as the transition from Vinyl to Cassette, have been investigated; most critical parameters that motivated the transition are identified; and dimensions that most drastically changed with the transition are quantified. Quality, cost, and performance of each recording format are discussed and metrics are generated to compare product generations. A
similar approach is followed to investigate the transition for the market demand from physical products to virtual products and eventually from virtual products to streaming services. Results of the most recent transition are deeply investigated. Leading companies as well as once successful companies in streaming services are studied. Factors that contributed to their success or failure are discussed. The impact of the transitions on the major stakeholders is examined.

The third chapter of the thesis makes a technical contribution based on mathematical models inspired from ecological research. Mathematical models have been used for many years to understand communities in nature. Examining two way and multi-way interactions involving pairs of species is a common practice in ecology and interactions such as mutualism, commensalism, competition, and predator-prey interactions. One of the commonly used modeling techniques in ecology research is Lotka-Volterra equations. In this chapter, these equations are briefly explained and their usage for the case of the music industry is detailed. To analyze product transitions in the music industry with Lotka-Volterra equations, a software package is created. This software package is provided in the Appendix of the thesis. Utilizing the software package, major phases in the recorded music industry are analyzed using two, three, or four technologies competing at the same time. Parameters of the model at each phase are discussed. The model is further utilized to make predictions for each phase. Each prediction from previous phases is compared to the actual values and the model is evaluated. To our knowledge, this part of the thesis constitutes the first example of Lotka-Volterra modeling in the music industry.

The last chapter summarizes learnings developed in the previous chapters, focusing and expanding on the recent transition to services in the music industry. Limitations and characteristics of this transition are further investigated to understand if other industries could go through a transition that is to some degree similar to the transition in the music industry. Both new and existing firms from other industries who adapted well to such transitions are examined with the purpose of understanding the critical points in their strategies that allowed them to execute such transitions successfully. Architectures of modern systems that reflect on the
transition, such as product as a service, are discussed. A few examples are given from the industry, in which some of the critical components are transitioning to a service model that resembles the ones in the music industry. The thesis ends with a discussion on business strategy for an effective transition.

Motivation

Issues regarding competition between new and existing technologies, and defensive response mechanisms for firms utilizing emerging technologies have been described in detail in the literature of technology strategy (Utterback, 1994). The emergence of new technologies into products can enhance or destroy existing competencies within an industry (Tushman and Anderson, 1986). Shifts in the technological environment of a specific industry, as well as the shifts in the external environment, can make the expertise and specific knowledge in the industry irrelevant (Henderson and Clark, 1990). At any given time in an industry’s history, core capabilities continue to evolve and only those who can manage such evolution can survive (Leonard-Barton, 1992).

The recorded music industry has gone through various technology-oriented transitions and it is currently in the middle of a transition where most of the sales revenue is not through physical or virtual products but rather via subscription services, changing the industry drastically. Music is rapidly adapting to “as a service” model, which has its roots in the software industry. With the emergence of cloud computing services, mobile devices, and the wide availability of cellular networks, consumers now can listen to virtually any music at any time they wish, without purchasing a physical or virtual product. Although the current dynamics of the music industry are further investigated in the following chapters, the motivation for this research relates the emergence of the new technologies to the interactions of emergent technologies with existing technologies.

In the literature, emerging technologies are perceived to be in competition with existing technologies. However, Pistorius and Utterback (1997) argued that the nature of interaction
among technologies was multi-modal and not limited to competition, as historically shown as the format of interaction among species in ecological science. As explained in Chapter 3, creating an easy to use software package to quickly evaluate hypotheses for the interactions among multiple technologies is one of the motivations for this research.

The results of the current transition in the music industry relates to a broader range of industries. Incumbents need to understand the magnitude of the threat coming from entrants with emerging technologies (specifically the ones motivating service transition in the music industry), new entrants need to optimize their offerings to gain a competitive advantage and industries overall need to develop an understanding of the limits of the service transitions.

**Basic Definitions**

Services traditionally include a variety of activities and it is difficult to arrive at a definition that every scholar will agree on. In fact, one of the scholars who studied service industries argued (Inman, 1989), “like beauty, the definition of the service activity is in the eye of the beholder.”

In the classical era, with respect to services, Adam Smith made the distinction between productive and unproductive labor. In his view, unproductive labor included servants of wealthy families or of the state. In his definition, he also included occupations that we include in the service sector today: writers, singers, the military, and lawyers. Heinrich Storch was one of the early classical authors who appreciated the value created by service activities. It is argued that during the First World War, all activity was considered as a service and the differences between goods and services were no longer relevant.

The classical view that only productive activities, with the original definition of production, create wealth is hard to justify given contemporary dynamics. Doctors, lawyers, and consultants can create wealth without production. On the other hand, the argument that there is no distinction between products and services, and that all activities are productive and they provide services,
is also hard to justify. For instance, we buy food to satisfy our hunger but defining food production as a service makes it hard to identify the components in product or service studies.

Grönroos et al. (2010) made a distinction between services and products based on the consumption process. They argued that products did not change during the consumption process and that they were fixed packages whereas services could evolve during consumption. However, a sharp distinction between products and services based on the consumption process raises several questions as well. For instance, it is very common for businesses to respond to consumers and go through a customization in their products. Such customization and modifications could be executed even during the sales process. On the other hand, service companies might have minimal interactions with their customers. For instance, the interaction between a cell phone service provider and its customers could be minimal and the contents of the service could be the same for a long period of time.

In recent years, there has been an increasing interest in product service systems (PSS), from the point of improvements in business’ capabilities of increasing the value they create and the point of lower environmental impact due to re-use cycles that such systems allow. Goedkopp et al. (1999) defined PSS as “a system of products, services, networks of “players” and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models.”

**Research Questions**

Chapter 2:

Which metrics motivated product transitions from one generation of use to the other in the music industry? What metrics changed for stakeholders with the latest transition to the streaming services? What new entrants and partnerships occurred in the industry because of transition? How did the emergence of streaming services impact musicians? How did the revenue structure change in the industry? How did the streaming change the way musicians earn their livings?
Chapter 3:
Can the Lotka-Volterra model provide insights into the dynamics of competition in the music industry? What did the Lotka-Volterra model parameters look like for each transition? Can the Lotka-Volterra model find solutions with reasonable insight with restrictions on competition? Can predator-prey relationships explain the nature of all competition or should researchers use a broader approach to competitions? Can the Lotka-Volterra model provide accurate forecasts for the technologies in the model?

Chapter 4:
What are main lessons a technology strategist can learn from the shifts in product generations in the music industry? Are there technology strategies that are robust if “as a service” model penetrates to an industry? Are there other models to represent transition in services? In which industries can we expect similar transitions? What are some examples of companies providing services comparable to streaming music? What are product architectures that can resist to such a transition? How should enterprises architect their organizational structure to embrace service transition? What are the main ideas and questions left to investigate for a successful technology strategy in the service transition?

Acknowledgment

Unless otherwise stated, all the tables and figures are illustrated by the author with given data sources and computer software.
Schumpeter (1934) argued that growth and development were direct products of the competitive process. Fitting well into Schumpeter’s statement, the music industry is extremely challenging for incumbents who cannot respond to innovation quickly. The music industry has a dynamic and global market with strong competition in every segment. As shown in the figure below, the major source of revenue has transitioned between physical products and then from physical products to virtual products, and lately from virtual products to services in the recorded music business. With the service approach, the consumption of music has become easier than it has ever been before. It is safe to assume that technological developments will continue to make it even easier to consume music for wider audiences.

![Figure 1 Inflation Adjusted US Recorded Music Revenues by Format (Source: RIAA)](image)

Music is an abstract product that based on information. It resonates in different ways among its listeners and performers hence it is not possible to agree on one common definition for music. Here’s a very brief list from some of the most prominent thinkers and musicians describing music:

---

“Music is a kind of counting performed by the mind without knowing that it is counting.”
G. W. Leibniz

“Music is the one incorporeal entrance into the higher world of knowledge which comprehends mankind but which mankind cannot comprehend.”
Ludwig van Beethoven

“Music is the occult metaphysical exercise of a soul not knowing that it philosophizes.”
Arthur Schopenhauer

“Music is something innate and internal, which needs little nourishment from without, and no experience drawn from life.”
Johann Wolfgang von Goethe

Capturing Value from Recorded Music

Unless it is captured into a physical medium, a song is in an abstract form. The transformation of this form has been studied extensively by Gillett (2011) – examining how it has changed from a piece of paper, to a rotating cylinder that can be played on a phonograph, to a vinyl record that can be played on a gramophone, to a cassette for a cassette player, and then to a CD for a CD player and to an MP3 digital music format. This story has been taught in many classrooms, discussed on various platforms, and continues to interest academicians from economy, business, and technology perspectives.

The research in this thesis relates to the distribution and consumption aspects of the music industry, which are again in the middle of a transformation in terms of its underlying technologies and the business model. Now, consumers have the luxury to choose from enormous libraries and to listen to almost any music any time they wish, without any significant delay and continuously. In most cases, consumers only need to make a payment if they choose not to listen to advertisements.

Such changes in the business model have brought new challenges. Sharing profits and capturing value from the subscription model are not clearly identified, as major streaming service firms in the market have not reached profitability yet. In this chapter, the music industry is investigated with a specific interest in its transition from products to services, with the hope that learnings
from music can guide technological transitions in other industries. Moving into a service based model does not only require changes in some concepts in the business units but it is a systematic change that reflects on the value chain and causes fundamental alterations in the interactions of stakeholders, value shared by the stakeholders for the entire business, as well as within the enterprise.

**Scope of This Research in the Music Industry**

Main stakeholders and activities in the industry are shown in the figures below.

<table>
<thead>
<tr>
<th>Primary Stakeholders</th>
<th>Secondary Stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artist agencies</td>
<td>Broadcasting organization</td>
</tr>
<tr>
<td>Artists, musicians, performers</td>
<td>Costumes, stylists</td>
</tr>
<tr>
<td>Distributors and wholesalers</td>
<td>Daily press</td>
</tr>
<tr>
<td>Equipment and software suppliers</td>
<td>Graphic design organizations</td>
</tr>
<tr>
<td>Instrument and studio equipment retailers</td>
<td>Hotels</td>
</tr>
<tr>
<td>Managers, assistants to the artists</td>
<td>Lawyers, auditors</td>
</tr>
<tr>
<td>Music Press</td>
<td>Photography organizations</td>
</tr>
<tr>
<td>Music Publishers</td>
<td>Restaurants, pubs, clubs</td>
</tr>
<tr>
<td>Music Retailers</td>
<td>Retailers that sell music in addition to main offering</td>
</tr>
<tr>
<td>Online Music Stores</td>
<td>Video production organizations</td>
</tr>
<tr>
<td>Record labels, producers, studios</td>
<td></td>
</tr>
<tr>
<td>Streaming services</td>
<td></td>
</tr>
<tr>
<td>Tour and concert producers</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1 Stakeholders in the Music Industry (Wikström, 2013)**

<table>
<thead>
<tr>
<th>Core Activities</th>
<th>Supporting Activities</th>
<th>Related Industries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration of copyright in composition and recordings</td>
<td>Education and training for music sector</td>
<td>Advertising</td>
</tr>
<tr>
<td>Live performances</td>
<td>Jingle production</td>
<td>Film and video</td>
</tr>
<tr>
<td>Management, representation, and promotion</td>
<td>Music for computer games</td>
<td>Interactive leisure software</td>
</tr>
<tr>
<td>Production, distribution, and retailing of sound recordings</td>
<td>Music for multimedia content</td>
<td>Internet / e-commerce</td>
</tr>
<tr>
<td>Song writing and composition</td>
<td>Music press</td>
<td>Performance arts</td>
</tr>
<tr>
<td>----------------------------</td>
<td>-------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Photography for music</td>
<td>Software and computer services</td>
<td></td>
</tr>
<tr>
<td>Production, distribution and retail of musical instruments</td>
<td>Television and radio</td>
<td></td>
</tr>
<tr>
<td>Production, distribution, and retail of printed music</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retailing and distribution of digital music via the internet</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 2 Main Activities in the Music Industry (DCMS, 1998)*

In this research, the technological developments and corresponding innovations that made the most disruptive and widely scaled impacts visible at the consumer level, related to production, distribution, and retailing of sound recordings are focused on. The goal of the research is to determine which metrics and dimensions triggered the adaptation of new technologies innovation to take place, how performances of offerings changed during the transitions, how the cost of listening to the music changed, how this cost radiated over major stakeholders, and what was the most critical dimension in the industry that allowed or yielded to the transition? Although the previous transitions are briefly covered, the focus is on the current dominant technology of streaming services. The parameters that made the streaming services as widely available as they are today are questioned, both from the technology and the business sides.

**Phonograph and Redefinition of the Music Publishing Industry**

In the 19th century, interest in music was a way to define the social class. Attending concerts and other musical events helped families to assert their social standing. The first mass distribution channel for the music, the “sheet music” was available and “After the Ball” by Charles K. Harris, became the first million selling song in a period of 12 months in the year 1892 (Ogden, 2011). One could easily find a piano in an upper middle class family’s home during that time. The concept of musical copyright and exclusive printing and publishing grants to certain individuals were commonly in practice. However, only the biggest stars received royalties from the sales of sheet music. In most cases, songwriters were paid per song by sheet music publishers.
When Thomas Edison introduced the phonograph to the world in 1877, he intended to provide an alternative way for the businessmen to communicate (Gitelman, 2003). Of course, at its early phases, the invention was not without problems initially. The Phonograph was difficult to operate except by the experts and the tin foil could not last for more than a few times of play. Edison continued to work on his invention to improve it for the masses.

About two decades later, the phonograph was in a better condition. First, it was cheaper than the initial version. From $150 in 1891, it went down to $20 (with adjusted inflation, worth approximately $550 today, quite close to the price of high quality stereo equipment) for the standard model and $7.50 (approximately $210 today) for the model known as “Gem” introduced in 1899. Secondly, it could play music. The initial version of the phonograph did not do well in the market until “nickelodeon” was introduced. A nickelodeon was a coin-operated phonograph that would play two minutes of music for five cents. It played standard-sized cylinders, 4.25” long and 2.1875” in diameter and they were sold at 50 cents each (worth $14 today). The device featured a variety of selections such as marches, sentimental ballads, coon songs, and comic monologues.

Naturally, there were issues with the improved phonograph as well. First, the cylinders only had 2 minutes of recordings and second, there were no processes in place to manufacture cylinders in mass quantity and performers had to repeat their performances during recording, increasing production costs. Despite such shortcomings, the phonograph made it possible for regular families to enjoy the music without purchasing an instrument, hiring a musician, or going to a musical event. Soon, it became the customers’ purchase of choice, replacing the sheet music.

Cost: The transition reduced the cost of listening to music significantly, especially for those who were not living in cities and had to travel to access to a musical event. Hence, savings in cost came in two dimensions: monetary savings and time savings. In 2017’s currency, each song cost $7 per minute to purchase.

Interactivity: The phonograph made it possible to interact with music. Before the transition, the audience was limited to what the musician had to offer, in the order the patron of the event had planned. With the phonograph, one could easily listen to classical music or American folk music by simply changing the cylinder. The Phonograph was not easy to operate at first. Storing

---

1 http://edison.rutgers.edu/tinfoilphono.htm (accessed in April 2017)
cylinders could become a problem quickly as each cylinder took ~16 square inches of space (corresponding to ~8 cube inches to store a 1 minute recording).

**Connectivity:** Invention made it possible for the ordinary citizens to connect with the popular artists as well as with the culture around them. It became possible to listen to the most famous musicians at the center of one’s home, office, barber shop, or an arcade store.

**Quality:** As the phonograph was the first technology to capture and play music, its sound quality was significantly poor.

### Following Product to Product Transitions

**Gramophone and 78 RPM**

Emile Berliner, having experience in Bell’s telephone, concluded that the wax cylinder was too soft and fragile to make a permanent recording as it would wear out quickly and it could not be mass-produced. Berliner thought of a disc based phonograph, which would be easy to manufacture in large quantities. Even though Edison had considered a disc phonograph, it was Berliner who patented it in 1877, naming it the gramophone\(^1\). Dimensions of the transition analysis from phonograph and cylinders to 78 rpm and gramophone are as shown below:

![Figure 4 Dimensions of the Transition from Phonograph Cylinders to 78 rpm Record](https://memory.loc.gov/ammem/berlhtml/berlgramo.html)

---

\(^1\) [https://memory.loc.gov/ammem/berlhtml/berlgramo.html](https://memory.loc.gov/ammem/berlhtml/berlgramo.html) (Accessed in February 2017)
**78 RPM and LP**
The LP (Long Play) record format was introduced by Columbia Records in 1948 and is still in use today. LP records allowed for a playing time of around 45 minutes, a substantial increase compared to 78 rpm records that had 3-4 minutes per side. This transition naturally occurred as the new technology was a much more efficient replacement of the old technology on every dimension (Keightley, 2004).

**LP to Audio Cassette**
The initial thought of utilizing magnetism for recording goes back to the 1880’s when Oberlin Smith¹ developed an idea for the technology after visiting Edison’s lab. However, it took a long time to develop a product utilizing magnetism for music. The reel to reel tape recorders were developed in Germany in the 1930’s, and Magnetophon was the first ever practical tape recorder, first demonstrated in Germany in 1935 at the Berlin Radio Show. However, reel to reel recorders required technical skills and had a limited market opportunity, although the functionality of being able to record at home seemed very attractive.²

The first attempt for products utilizing reel to reel tapes in cartridges came from RCA. Similar to the cassettes, RCA’s cartridges were reversible and each side could be played. At a dimension of 5” x 7.125” x 0.5”, the cartridges could record 30 minutes of audio.³ In the following years, 8-track (also known as STEREO 8) was introduced by Lear Jet Corporation. 8-track was inspired by RCA’s cartridge and was designed to reduce mechanical complexity, incorporating a neoprene rubber and nylon pinch roller into the cartridge itself.

The Compact Cassette was released by Philips in 1962 (with Norelco brand in the US in 1964). The format initially offered poor sound quality and it targeted voice recording and dictation applications. However, it didn’t take long to improve the format to play higher quality recordings

---

and support stereo sound. It is important to note that some of the improvements were originated from external contributions such as Dolby. Portability of the cassettes was a significant advantage over LP and vinyl. The creation of the Walkman contributed significantly to the cassette's fate, as it allowed consumers to listen to music anywhere. Record time was another critical parameter for the success of the cassette over the LP. Depending on the variety, cassettes could play around 30 minutes per side. Manufacturers tested the limits with extremely thin tapes. For instance, Maxell's UR 150 could play 150 minutes (75 minutes per side).

![Figure 5 Dimensions of the Transition from LP to Compact Cassette](image)

**Audio Cassette to Compact Disc**

CD technology was introduced as a result of a partnership between Sony and Philips in 1982 (1983 in the US). Most of the physics related to the manufacturing of the CD was developed by Philips whereas digital audio expertise was provided by Sony. Early cooperation between these two industry giants constitutes an interesting case and perhaps is one of the reasons for the wide popularity of CD technology as the partnership prevented each company from falling into a competition based on the standards. CD technology introduced a significant point in the media storage field as it was the first example of using optics to store data (Immink, 1998). CD sales quickly reached to the sales of vinyl and the cassette. It is worthwhile to note that in the first years of the CD, the available music in CD format was mostly classical music as the decision makers in the music hardware and recording industries had assumed that the early adapters of high quality recording products would be those who were listeners of classical music (Butterworth, 1977).
Unlike Vinyl records, CD’s could be played in cars, on portable listening devices like Sony Discman, most DVD players, as well as laptop and desktop computers. This wide range of options in the players brought CDs into many more modes of storage, use, and arrangement than cassettes or vinyl records. In addition, users could easily select a song on a CD and play it instantly, providing an immediate advantage for the CD over any previous format (Straw, 2009). Compared to cassettes, CDs were easier to remove from their packages and could be arranged in small binders, suitable for automobile drivers.

CD technology also introduced digital technologies to the music playing for the first time. It used 44.1 kHz sampling with 16-bit resolution, introducing A/D conversion, error correction encoding, and EFM modulation resulting in 4.3 Mbit/s data rate.

![Diagram: Dimensions of the Transition from Audio Cassette to Compact Disc]

**Figure 6 Dimensions of the Transition from Audio Cassette to Compact Disc**

**Transition from Physical Products to Virtual Products**

As previously mentioned, the research in this thesis relates to the major product transitions in the recorded music industry, however, as in many other industries, music recording had been under the impact of innovations in other areas such as analog to digital transformations or improvements in computer hardware, data compression technologies, etc. One of these data compression, formatting technologies, MP3 was extremely impactful in the fate of the music industry.
MPEG-2 audio layer III, or as more commonly referred to as MP3, is an audio coding format for digital audio, utilizing lossy data compression. MP3 is a result of a lossy data compression algorithm that takes advantage of imperfections in human hearing. Since MP3 applies a selective compression, it yields smaller file sizes for music files compared to the ones in CD format. MP3 made it possible to put thousands of songs into a hard drive, changing not only the fate of the music industry, but the fate of many companies as well.

One of the companies whose fate significantly changed with the MP3 format was Apple Inc. (Apple), an American multinational technology company. In 2001, Apple sales fell to $5.4 billion from $8 billion and the company was looking for ways to generate revenue. In the same year, Apple launched the iPod and introduced the concept of a digital hub. With a digital hub, Apple with its hardware and software products, would provide a platform for home users to maximize the utility of their new digital devices such as digital music players, personal digital assistants, cameras, etc.

There had been unsuccessful attempts from startups and incumbents to develop an MP3 player such as Iomega’s HipZip\(^1\) and Remote Solutions’ Personal Jukebox\(^2\). To ensure success, Apple developed all of the critical components inside the organization: The music player, the music store, and the software to run on the users’ computers to control the player. This approach created a successful ecosystem serving well for the consumers. Portable iPods made it possible to bring 1,000 songs into customers’ pockets. iTunes allowed consumers to burn songs from CDs they already owned to MP3 format to be listened to on their iPods. When the company introduced iTunes music store in 2003\(^3\), it started selling music and quickly became the largest legal digital music retailer.

---

\(^1\) [http://www.pcmag.com/article2/0,2817,79059,00.asp](http://www.pcmag.com/article2/0,2817,79059,00.asp) (Accessed in February 2017)


Here the motivation of transition was not only due to the successful strategy from Apple but also due to the benefits of Mp3 format such as with the ease of sharing music between users and the wide acceptance of the format with illegal file sharing websites. One of the illegal file sharing services was Napster. Although there were already similar networks that organized distributing files across the internet, Napster quickly became the most popular file sharing platform for music files after its launch in June 1999\(^1\). It spread so quickly that by March of 2000, Napster had 20 million users and started getting attention from the Recording Industry Association of America (RIAA). Napster allowed users to share MP3 files with other users without any fee, causing illegal distribution of the copyright material. After RIAA’s lawsuit, Napster closed its doors in July 2001.

\[\text{Figure 8 Dimensions of the Transition from Physical Products to Virtual Products}\]

Metrics for Transitions

The analysis suggests that the transitions have been motivated by the combination of the following dimensions:

**Cost per minute**

The products that dominated the market either reduced the cost for listening to songs per minute or matched the cost of the existing solutions but exceeded their performance in another dimension. The following chart shows the cost per minute of song for each technology mentioned above in 2016’s dollars\(^1,2\).

![Cost of Listening to One Minute of Song](image)

*Figure 9 Cost of Listening to One Minute of Song from 1973 to 2015 in Today’s Dollars*

**Portability**

The products that reduced the amount of space to store and play musical recordings have reached market dominance. The following data shows the volume per minute of song for each

\(^1\) Note that the capacity of mediums improved over time. The capacity of a technology as it was first introduced, is taken as the base for the calculation

\(^2\) Illustrated from RIAA data
studied technology. Note that a more comprehensive study for player sizes is possible by taking a large sample size from the market and conducting a statistical analysis.

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Example Product</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portable LP/EP Player</td>
<td>Jensen JTA-230 3 Speed Stereo Turntable*</td>
<td>1175 cubic inches</td>
</tr>
<tr>
<td>Portable Cassette player</td>
<td>Craig Electronics CS2301A Cassette Player</td>
<td>29 cubic inches</td>
</tr>
<tr>
<td>Portable CD player</td>
<td>GPX PC101B Portable CD Player*</td>
<td>32.5 cubic inches</td>
</tr>
<tr>
<td>Portable MP3 player</td>
<td>Sandisk 8GB Clip Jam MP3 Player*</td>
<td>2.6 cubic inches</td>
</tr>
</tbody>
</table>

*Best seller in Amazon in its category

Table 3 List of Products Used in the Study.
Transition from Virtual Products to Streaming Services

Streaming Failures: MusicNet and PressPlay
To prevent further penetration of illegal file sharing networks and to capitalize on existing internet technologies that allowed streaming music, three of the five major labels, Time Warner, EMI, and Bertelsmann initiated MusicNet. In parallel, Vivendi Universal and Sony created PressPlay. Both services were early forms of music streaming services. Since these 5 companies controlled 80% of all commercial music, MusicNet and PressPlay could virtually control the entire music industry with the right strategy. However, both services failed as expected by the analysts of the time. The arguments of the industry analysts regarding streaming services were valid then and they are still valid today (Bloom, 2001).

- Accessibility: In MusicNet, users could download songs but they could not transfer them to their MP3 players or to other computers. In PressPlay, users could not even download the files.
- Connectivity: Neither service provided connection to the entire artistic world. Since Sony and Vivendi allowed connection to their own networks, PressPlay customers would not have access to the artists of the other 3 brands. The scenario was the same for MusicNet customers as well.

Streaming Success: Spotify
Spotify is a music streaming service that was launched in October 2008 by Daniel Ek and Martin Lorentzon in Stockholm, Sweden. The company operates globally and its application, which lets users stream music, currently runs on mostly accepted smartphone and computer platforms. Although it is a relatively new company, Spotify changed the music business significantly. Before the wide acceptance of Spotify, users would buy CD’s and digital music, mostly from the iTunes store or download illegal music. Spotify gave consumers an option to listen to the music of their choice, any time, either for free (with advertisements) or with a paid premium account (without advertisements). Here are the changes that Spotify (followed by other streaming services) introduced to the music industry:
Although consumers had several options to listen to music legally for free over the radio, TV, Pandora (internet radio), they had to pay to listen to the music of their choice at any given time in most cases. Spotify changed that by introducing a large library that is free to listen to immediately.

Before Spotify, there was no mechanism to pay artists based on how many times their songs were played. Consumers could purchase a CD or an MP3 and listen to the songs an unlimited number of times.

Spotify follows Freemium pricing model to distribute its application. Freemium is a pricing strategy around the idea of offering a product or service (typically digital as of today) for free of charge but later charging for additional features and functionality. Freemium services' primary aim is to convert non-paying users into paying customers (Wagner, 2013). Artists are represented by music labels, which are paid by Spotify on the basis of a royalty. As of September 2016, Spotify had paid $5bn to the rights holders.

Spotify has been widely successful in gaining users worldwide, achieving exponential growth in between 2010 and 2016, growing from 1 million paid users in March 2011 to 40 million in September 2016. As of April 2017, Spotify has over 30 million songs, 50 million subscribers, 100 million active users, and it is available in 60 countries.

Figure 12 Spotify Membership Types (Source: Spotify)

---

Spotify had the following significant factors contribute to its success to become an attractive platform that any digital content provider needs to learn from:

1. Spotify benefited labels and artists by preventing illegal downloads and awarded successful artists. Not only did it benefit major artists, it also made it possible for individual artists to upload their work on the platform and monetize easily.

2. From a technology perspective, it has been available on all common operating systems and it is independent of a user’s network or service providers (performing equally well on AT&T, Verizon, etc.). It has been successful in forming partnerships with enterprises from various industries as shown in the diagram below.

3. Without any doubt, Spotify owes some portion of its success to network effects. One of the most attractive features of the platform from the early days was integration into social media platforms such as Facebook to share the songs that customers enjoyed (Stutzman, 2013). Sharing what customers enjoyed with each other has led to one of the most attractive features of the platform which is recommending songs and finding new songs based on other users who share similar interests.
Dimensions Changed with Streaming

**Cost:** As long as the end customer is willing to listen to advertisements and has an active internet connection, there is no cost to listening to music at Spotify. Hence the previously investigated parameter, cost per minute of song, is $0.00 for Spotify’s free service. According to a survey from Nielsen, 93% of the U.S. population listens to music, spending more than 25 hours each week\(^2\). The cost isn’t that high for the premium members either. A premium Spotify member who pays $9.99 a month and who listens to the average 25 hours of music, pays $0.0016 per minute of music, substantially lower than the average $0.28 per minute on digital downloads or $0.14 per minute on CD’s.

**Portability:** Spotify is available on all major computers and smartphones, providing a high level of portability. Only Sirius or other satellite based radio service providers achieve higher portability than Spotify since they do not require an active internet connection while driving the car. On the other hand, because they are satellite radios, they do not provide customization service at the level Spotify does.

**Interactivity:** Spotify offers play lists and recommendation services that are automatically customized based on customers’ previous interests.

---

Major Changes in Stakeholders with Streaming

Artists

With the introduction of streaming services, it has become nearly impossible for artists to live on solely their earnings from selling music. The table below shows how a musician can reach the US monthly minimum wage of $1,160 by selling music on different platforms or as a product.\(^1\)

<table>
<thead>
<tr>
<th>Format</th>
<th>Price</th>
<th>The musician needs to sell</th>
<th>Revenue to label</th>
<th>Revenue to artist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-pressed CD</td>
<td>$9.99</td>
<td>143</td>
<td>$0.000</td>
<td>$8.000</td>
</tr>
<tr>
<td>CD album</td>
<td>$9.99</td>
<td>155</td>
<td>$0.000</td>
<td>$7.500</td>
</tr>
<tr>
<td>Retail album CD with royalty deal</td>
<td>$9.99</td>
<td>1,161</td>
<td>$0.000</td>
<td>$1.000</td>
</tr>
<tr>
<td>Album download</td>
<td>$9.99</td>
<td>1,229</td>
<td>$1.000</td>
<td>$0.940</td>
</tr>
<tr>
<td>MP3 download (non iTunes, independent)</td>
<td>$0.99</td>
<td>1,562</td>
<td>$5.350</td>
<td>$0.940</td>
</tr>
<tr>
<td>MP3 download (iTunes)</td>
<td>$0.99</td>
<td>2,044</td>
<td>$0.000</td>
<td>$0.570</td>
</tr>
<tr>
<td>Retail album CD with low royalty deal</td>
<td>$9.99</td>
<td>3,871</td>
<td>$1.700</td>
<td>$0.300</td>
</tr>
<tr>
<td>Track download</td>
<td>$0.99</td>
<td>12,399</td>
<td>$0.530</td>
<td>$0.090</td>
</tr>
<tr>
<td>Rhapsody Stream subscription</td>
<td></td>
<td>849,817</td>
<td>$0.00910</td>
<td>$0.00220</td>
</tr>
<tr>
<td>last.fm subscription</td>
<td></td>
<td>1,546,667</td>
<td>$0.00400</td>
<td>$0.00075</td>
</tr>
<tr>
<td>Spotify</td>
<td></td>
<td>4,053,110</td>
<td>$0.001600</td>
<td>$0.000290</td>
</tr>
</tbody>
</table>

*Table 5 Music Format and Required Sales for a Minimum Monthly Wage*

As can be seen from the table above, streaming could only generate significant revenue for popular artists. But the story is not only sad for new and undiscovered artists. The internet and widely available streaming services have made it possible for small bands to release their recordings in a cost-effective way to a potentially wide audience. New technologies allowed talented stars to be discovered. For instance, Canadian singer and songwriter Justin Bieber was discovered by a talent manager who saw his YouTube videos covering songs in 2008.\(^2\) Crowdsourcing technologies allowed artists to engage with their fans and to create content together. It has become quite common for new or even famous artists to crowdfund their albums on platforms like Indiegogo or Kickstarter. Technology brings opportunities but requires a more entrepreneurial edge from artists.

---


Unexpected New Stakeholders

As technology lowered the barriers to entry to produce music, we’ve seen retailers or energy drink companies enter the music business. Here are a few examples:

In 1999, Starbucks acquired a small company, Hear Music, along with other motivations, to establish a record label and bring revenue from music sales. The acquisition included the five CD stores that Hear Music operated, which were remodeled to include Starbucks coffee bar. Here’s the list of stores: (1) Berkeley, California (Closed 7-30-07), (2) Palo Alto, California (Closed 6-24-04), (3) Santa Monica, California (Closed 1-26-2009), (4) Sony Metreon, San Francisco, California (Closed 10-15-00), and (5) Chicago, Illinois (Closed 1-28-02).

In 2004, Starbuck’s chairman Howard Schultz said, “We believe strongly that we can transform the retail record industry.” On March 11, 2007, Starbucks and Concord Music Group announced that they had formed a new record label, Hear Music, to forge relationships directly with artists and distribute recordings at Starbucks locations as well as through traditional music channels. The idea was to leverage the chains’ footprints and loyalty to sell a small amount of CDs at coffee shops. This partnership attracted big names such as Paul McCartney and Joni Mitchell.

Currently, Concord music continues to operate the Hear Music Label and by February 2015, Starbucks decided to stop selling CD’s in their stores. However, the coffee shop is now focused on forming partnerships to create a “music ecosystem”. “For over 40 years, music has played a vital role in Starbucks Third Place experience – inspiring our partners and customers in unexpected ways that have helped to shape the global pop culture. And we are delighted and honored to bring Spotify directly to our customers,” said Howard Schultz, chairman and CEO of Starbucks. “Throughout its history, Starbucks has worked closely with the music industry, offering a variety of artists a platform for their work. By connecting Spotify’s world-class streaming

platform into our world-class store and digital ecosystem, we are reinventing the way our millions of global customers discover music.”

Red Bull, an energy drink company who offers caffeine like Starbucks, also followed Starbucks to enter into the branded record label business. Launched in Santa Monica, California in 2007, Red Bull Records positions itself as an opportunity provider Label for small indie bands to record their music for free. The label has worked with bands such as Gojira, whose live band has won awards¹.

Another unexpected group of stakeholders is vinyl manufacturers. Once near extinction, vinyl made a comeback in recent years. Sales of vinyl reached a 25 year high in 2016², despite various technical disadvantages, such as limited lifespan, lack of portability, lower sound quality, etc. Vinyl’s comeback certainly constitutes an interesting case. Some industry experts attribute vinyl’s comeback to nostalgia but the flaw in that argument is that there is a strong demand for vinyl’s among teenagers, who have never even seen a table top before.

![Figure 14 LP/Vinyl Album Sales in the USA (Source: Nielsen Music U.S. Report 2016)](image)

---


Chapter 3: Analysis of the Transitions in the Music Industry with Lotka-Volterra Equations

This chapter makes a technical contribution to develop insights into the transitions in the industry, utilizing mathematical models inspired from ecology. In this chapter, Lotka-Volterra (LV) system equations are utilized to develop insights regarding the transitions in the recorded music industry. First, a very brief history on technology and business modeling inspired by ecology is presented. Second, Lotka-Volterra equations, as well as their solutions, are introduced. The development of the software package to conduct the analysis of this chapter is explained in the following part. Selected techniques to use the LV model to develop insights into the history of the transitions in the industry are shown. In the analysis part, sales data for the recorded music industry is divided into four phases and each phase is investigated in detail. Benefits as well as limitations of the utilized LV model are discussed and points for further improvement are highlighted. Several improvements into the LV model are discussed and a portion of them are implemented. The current phase of the recorded music industry is further investigated and discussed.

Ecology and Business Modeling

Research in ecology has previously inspired research in technology in the growth formulation and forecasting areas. Models such as Bass (Bass, 1969), Pearl (Pearl and Reed, 1920), and Fisher-Pry (Fisher and Pry, 1971) have been used in modeling technological competition in previous work.

The Pearl model is one of the most known models inspired from ecology and used in management modeling. Since it relates to the Lotka-Volterra model, it is briefly explained here. In the Pearl model, the logistic equation is used to emphasize that the size of the population implies a negative feedback on the population growth rate. The rate of growth declines as the population size increases, eventually yielding to an equilibrium size for the population, which is known as the carrying capacity. Hence, the Pearl model can be formulated as:
\[
\frac{dP}{dt} = rP \times \left(1 - \frac{P}{K}\right)
\]  

(1)

Simple takeaways from this equation are:

- When the population is very small \((P = 0)\), the growth of the population would be exponential as a factor of \(r\)
- As the population size gets smaller, the growth will decay
- When the population is around the carrying capacity of the habitat, \(K\), the growth will stop.

The Lotka-Volterra equation system consists of two first order non-linear, differential equations that are used to explain dynamic interactions between two species (Lotka, 1920). This system is frequently used to describe the dynamics of ecological systems in which two species interact in predator and prey form, hence Lotka-Volterra equations are often called predator-prey equations. The change in the populations is explained in the following equations:

\[
\begin{align*}
\frac{dX}{dt} &= X(\alpha - \beta Y) \\
\frac{dY}{dt} &= Y(\delta X - \gamma)
\end{align*}
\]  

(2)

Where, \(X\) is the prey population, \(Y\) is the predator population, and \(\alpha, \beta, \gamma, \delta\) are positive real numbers that are used as parameters to describe the interaction of two species. At its core, the Lotka-Volterra model suggests that:

- Interaction between the modeled species are driven by their rate of growth
- The prey population is assumed to grow exponentially (unlimited food supplies are assumed) and the limit of the prey population is set by parameter \(\beta\) and the predator population.
• The predator population however strictly depends on the prey population and if there is no prey population ($X = 0$) then the predator population exponentially decays.

**Modified Lotka-Volterra Equation to Analyze Interactions Among Technologies**

In this study, a modified version of the Lotka-Volterra model is used to examine the transitions in the music industry, by forecasting the interactions among technologies. More details and specifics on the modified Lotka-Volterra model that is used for this study can be found in Pistorius and Utterback (1997). However, the basics of the model are as explained below:

In the Lotka-Volterra model, the system of equations that describe the interaction between two groups can be expressed as in Pistorius and Utterback (1996).

\[
\begin{align*}
\frac{dN}{dt} &= a_n N - b_n N^2 + c_{nm}NM \\
\frac{dM}{dt} &= a_m M - b_m M^2 + c_{mn}MN
\end{align*}
\]  

(3)

Where, $N$ and $M$ are technologies in some form of an interaction in the predator population, $c$ is a real vector, and $a$ and $b$ are positive real vectors that are used as parameters to describe the interaction. Takeaways from the model are:

• Each technology is modeled by an equation that contains a logistic differential equation and a term that emphasizes the interaction between technologies
• Interactions between the modeled species are driven by their rate of growth, similar to the original Lokta-Volterra model
• Growth of a technology can have a positive or negative impact on the growth of other technology, which is expressed as the sign of the coefficient $c$
The last statement is especially critical as it is the foundation of the model. The model yields to the following framework to consider the interaction among technologies (Pistorius and Utterback, 1996):

- **Pure Competition:** In this case, all of the variables in matrix $c$ are negative and the growth of a technology negatively impacts the growth of the other technology.
- **Symbiosis:** In this case, all variables in matrix $c$ are positive, implying a positive impact induced by the growth of a technology onto the growth of other technologies.
- **Predator and Prey:** In this case, some variables in $c$ are positive and some are negative, implying that one of the technologies induces growth on the other and the other technology induces decay on the other technology.

This approach perhaps best can be shown in the diagram below:

![Impact of Technology 1 on Technology 2](image)

*Figure 15 Framework for interactions among technologies (Pistorius & Utterback 1997)*

**Generalization, Solution, and Analysis of the Modified Lotka-Volterra Equation**

Assume that $J$ technologies compete in the same market (ways to represent a technology will be further investigated). Also assume $T_i(t)$ represents technology $i$. Based on equation (3), the differential equation for $T_i(t)$ can be expressed as:
\[
\frac{dT_i}{dt} = a_i T_i + \sum_{j=1}^{J} c_{ij} T_i T_j
\]  \hspace{1cm} (4)

where \( c_{ij} = b_i \) for \( i = j \). The sign of \( c_{ij} \) determines the type of influence of one technology on the other technology. Although various papers discuss the constraint on \( c_{ij} \) which is \( c_{ij} > 0 \) for \( i = j \), in this study, this condition is discussed and the benefits of relaxing the constraint are shown.

A general solution for multi technology, multi-mode interaction can be formulized as the following:

\[
T_i(t + 1) = \frac{e^{a_i T_i(t)}}{1 - \sum_{j=1}^{J} \frac{c_{ij}(e^{a_i} - 1)}{a_i} T_j(t)}
\]  \hspace{1cm} (5)

One can easily drive the following intuition from the formula:

- For a technology \( i \), if there is no interaction between this technology and other technologies, \( (\forall i, j : c_{ij} = 0) \) then this technology would grow exponentially with a rate determined with its \( a \) coefficient.

- If a technology \( i \), has low interactions with other technologies, then the denominator of the equation approaches to 1, yielding an exponential growth for the technology, with a rate determined with its \( a \) coefficient.

- If a technology \( i \), has high and positive (symbiosis, predator) interactions with other technologies, then the denominator of the equation approaches to 0, yielding an exponential growth for the technology, at a higher rate compared to the rate determined with its \( a \) coefficient.

- If a technology \( i \), has high and negative (competition, prey) interactions with other technologies, then the denominator of the equation approaches to \( \infty \), yielding a decay for the technology depending on its \( a \) coefficient.
Analysis Technique

A software package to easily solve the Lotka-Volterra equation or to find parameters for the given data sets has been developed using Matlab™ programming language. Using this software, historical music recording sales data have been investigated to develop insights from the transitions in the music industry. This chapter explains techniques to use the non-linear least square optimization method to find parameters in the modified Lotka-Volterra model.

The Matlab™ software package developed for the method is provided in the Appendix of the thesis. As shown in Formula (5), a technology $i$ (whether in market share, consumption in units, sales revenue, etc.) can be modeled as a function:

$$T_i(t, c, a)$$  \hspace{1cm} (6)

Where $t$ is time, $c$ and $a$ are parameters of the modified Lotka-Volterra model. Given the actual data $D_i(t)$, which is in the same units as $T_i$, an optimization goal to minimize the normalized sum of squared errors can be defined as:

$$\arg\min_{a \in [0,\infty), c \in \mathbb{R}} \sum_{i=1}^{J} \sum_{t=1}^{N} \left( \frac{D_i(t) - T_i(t, c, a)}{D_i(t)} \right)^2$$  \hspace{1cm} (7)

where

$N$ is the number of discrete data points available
$J$ is the number of technologies modeled

**Trust Region Reflective Algorithm and Genetic Algorithm**

To solve for the optimal parameters, the trust region reflective algorithm provided with Matlab Optimization Toolbox (users will need this toolbox to run our code) is used. The term “Trust region” refers to the subset of the region of the objective function that is approximated using a
model function. Specifics of the optimization algorithm are beyond the scope of this thesis. However, a rich set of studies and explanations can be found in Coleman’s (Coleman, 1996), or Byrd’s (Byrd, 2000) works.

To solve the Lotka-Volterra equation for optimum parameters with the trust region reflective algorithm, it is critical to determine the initial parameters to pass into the optimization engine. For that task, an approach inspired by a genetic algorithm is used. The genetic algorithm is a general use algorithm used in constrained and non-constrained optimization problems. In the genetic algorithm, an initial solution is selected from a pool of possible options with previously determined selection rules and it evolves during the solution process. Interested readers are encouraged to find more details on the genetic algorithm in Deb’s (Deb et al., 2002) or Morris’s works (Morris et al., 1998).

In this research, a simple implementation of the genetic algorithm is used to create random solutions and select the best of them to re-evaluate as a solution. Specifically, a pool of 100 random parameters for $c$ and $a$ are generated and passed to the optimization engine to use as initial parameters. At the end of each optimization, results from the optimization engine as well the parameters and the residue, as defined in formula (8), are stored.

$$Residue(t, i) = \left( \frac{D_i(t) - T_i(t, c, a)}{D_i(t)} \right)^2$$

In the second phase, a random error at a smaller magnitude is added on top of the previously selected parameters to be resubmitted back to the optimization engine. Optimization breaks if there is no improvement in the second step of the genetic algorithm. If there is an improvement, the optimization iterates back to adding random errors. The approach to the optimization task is as explained in the following figure.
Methodology to Analyze Music Industry Data

The approach to analyze the music industry to learn from transitions is as follows:

- The data from the recording industry is divided into four phases, driven by the dominant technologies of each phase
- Each phase is then simulated with the Lotka-Volterra model, and the coefficients and interactions between technologies is discussed in detail.
- Using the results from the simulations, limited predictions are made and compared to the actual results
Our data set starts at 1973. The Lotka-Volterra simulations are conducted for four different phases of transition.

- **Phase 1:** Starts at 1973, where the earliest data is available and ends in 1983, when the sales revenue of new Cassette technology catches the sales revenue of the incumbent Vinyl.
- **Phase 2:** The CD enters the market and catches the sales revenue of the incumbent Cassette
- **Phase 3:** The CD reaches its peak and starts to decline where Cassette sales disappear
- **Phase 4:** This phase extends to today, where streaming technologies enter the market and the market share for CD’s declines

The format to visualize the simulation results for the Lotka-Volterra model is as shown below.
A table like Table 7 will be used in the following parts of the thesis to analyze the results of the Lotka-Volterra simulations for each case. Although the table presents the format for a 2-technology case, it is easy to develop intuition for more technology cases as well. The explanation for the coefficients mentioned in the table is as stated below:

Even though in some of the previous work, self-coupling coefficient has been determined to be exclusively positive, in this research, it will be shown that relaxing this criterion improves the
understanding of the competitive behavior and yields better agreement between the data and the model.

**Analysis Results**

**Analysis of Phase – 1**

Phase 1 is first analyzed by providing input for years 1973 – 1984. Optimum parameters found by the optimization engine as well as the analysis results are given below.

<table>
<thead>
<tr>
<th>c</th>
<th>Vinyl</th>
<th>Cassette</th>
<th>8 Track</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinyl</td>
<td>8.70E-05</td>
<td>1.92E-04</td>
<td>8.83E-06</td>
</tr>
<tr>
<td>Cassette</td>
<td>1.81E-03</td>
<td>2.62E-03</td>
<td>5.18E-04</td>
</tr>
<tr>
<td>8 Track</td>
<td>8.56E-04</td>
<td>3.15E-03</td>
<td>3.15E-03</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>s</th>
<th>Vinyl</th>
<th>Cassette</th>
<th>8 Track</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinyl</td>
<td>-1</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>Cassette</td>
<td>-1</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>8 Track</td>
<td>-1</td>
<td>-1</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>a</th>
<th>Vinyl</th>
<th>Cassette</th>
<th>8 Track</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinyl</td>
<td>9.430E-01</td>
<td>2.467E+01</td>
<td>1.796E-09</td>
</tr>
</tbody>
</table>

*Table 8 Model Parameters Phase-1*
Related to the nature of interactions, given the data from 1976 to 1984, analysis shows that:

- **8-Track**: Cassette has a predator-prey relationship, where Cassette is the predator
- **8-Track**: Vinyl has a predator-prey relationship, where Vinyl is the predator
- **Cassette**: Vinyl has a competitive relationship

On the other hand, the analysis shows 8-Track’s sales revenue will become $0. In a true predator-prey relationship, the prey does not entirely disappear but it comes back once the predator population starts to decay. However, one should read this result as a decay in the 8-track’s sales revenue results as an increase in Vinyl’s and Cassette’s sales revenue, and that the increase in Vinyl’s and Cassette’s sales revenue results in a decrease in 8-Track’s sales revenue.

The analysis indicates that the nature of interaction between Vinyl and Cassette is competition, which would result in Vinyl’s sales revenue disappearing at some point, until a change in the interaction occurs. As Darwin noted, two species cannot stay in competition forever (Darwin,
Hence, had an analyst ran the LV simulation in 1984 and expected for Vinyl and Cassette to continue to compete, she should expect one of two technologies to disappear.

Analysis also shows a negative optimum self-coupling of values for Vinyl and Cassette. Negative self-coupling can be argued as a result of competition. The reason for scholars to restrict self-coupling to positive numbers is that self-coupling is generally utilized to introduce a limit to the growth of the technologies. However, the Lotka-Volterra models introduce competition and, depending on the nature, competition can also introduce a limit to the growth. Hence in this study, the sign on the self-coupling is relaxed. The following study shows that constraining self-coupling to positive values reduces the adaptability of the model to the data.

It is also important to note that analysis shows the nature of interaction changes over time as expected. For the phase under investigation, between 1973-1975, the sales revenue from Cassettes was significantly under Vinyl’s but it was on the rise whereas Vinyl sales were stable. The following are the results of the study to investigate the interaction with only early data.
Now we encounter an interesting result. Here are the interactions in the early years of cassette:

- 8-Track: Cassette has a symbiotic relationship
- 8-Track: Vinyl has a predator-prey relationship, where Vinyl is the predator
- Cassette: Vinyl has a predator-prey relationship, where Vinyl is the predator

One can expect to have changes in the interactions among technologies over time. However, in this analysis, the number of the data points for the Cassette is limited to arrive to a conclusion.
Analysis of Phase – 2

Phase 2 is analyzed by providing input for 1982 – 1990. Optimum parameters found by the optimization engine as well as the analysis results are given below.

<table>
<thead>
<tr>
<th>LV Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>c</td>
</tr>
<tr>
<td><strong>Vinyl</strong></td>
</tr>
<tr>
<td>Vinyl</td>
</tr>
<tr>
<td>Cassette</td>
</tr>
<tr>
<td>CD</td>
</tr>
<tr>
<td>s</td>
</tr>
<tr>
<td><strong>Vinyl</strong></td>
</tr>
<tr>
<td>Vinyl</td>
</tr>
<tr>
<td>Cassette</td>
</tr>
<tr>
<td>CD</td>
</tr>
<tr>
<td>a</td>
</tr>
<tr>
<td><strong>Vinyl</strong></td>
</tr>
<tr>
<td>Vinyl</td>
</tr>
<tr>
<td>Cassette</td>
</tr>
<tr>
<td>CD</td>
</tr>
</tbody>
</table>

*Table 10 Model Parameters Phase-2*

![Figure 21 Phase-2 Analysis](image-url)
Related to the nature of interactions, analysis shows that:

- Vinyl: The CD has a predator-prey relationship, where CD is the predator. The coefficient that determines this interaction is the largest coefficient among the coefficients for CD.
- Cassette: The CD has a predator-prey relationship, where CD is the predator.
- Cassette: Vinyl has a symbiotic relationship.

This result is hardly surprising as the CD took market leadership during the early 1990s, moving revenue away from Cassette and Vinyl. Although the LV model correctly predicts the near future as sales continued to grow for the CD and reduce for Cassette, it is important to emphasize that LV is not a pure forecasting tool but more of a tool that provides insight regarding the nature of interactions among technologies.

These results also beg the question: How early can LV predict emergence of a new technology? The answer seems to be in the optimization engine. As shown in the figure below, if one simulates the very early years of CD, the LV model may not be able to predict the emergence of a new technology. This is not purely due to the limitation of the model but it is also due to the decisions one makes to simulate the model and to find optimum parameters. Since in the solution provided with this thesis, the residue for the optimization engine would be much smaller in the case of the CD compared to Vinyl or Cassette (because they have higher sales revenue), the LV model does not predict the emergence of the CD in its first 2-3 years. The result of the mentioned analysis is shown in the figure below.
Analysis of Phase – 3

Phase-3 is not particularly interesting as it has the CD reaching its peak and the cassette’s decline. However, it presents a case for 2 technologies competing instead of 3 as in previous examples.

**LV Coefficients**

<table>
<thead>
<tr>
<th></th>
<th>CD</th>
<th>Cassette</th>
</tr>
</thead>
<tbody>
<tr>
<td>c</td>
<td>CD</td>
<td>Cassette</td>
</tr>
<tr>
<td></td>
<td>1.30E-05</td>
<td>8.94E-06</td>
</tr>
<tr>
<td></td>
<td>Cassette</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.60E-05</td>
<td>4.99E-06</td>
</tr>
<tr>
<td>s</td>
<td>CD</td>
<td>Cassette</td>
</tr>
<tr>
<td></td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Cassette</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>a</td>
<td>CD</td>
<td>Cassette</td>
</tr>
<tr>
<td></td>
<td>2.379E-01</td>
<td>2.333E-10</td>
</tr>
</tbody>
</table>

*Table 11 Model Parameters Phase-3*
As shown in the table, a coefficient for the Cassette is near zero and LV explains the decline with the predator-prey relationship where Cassette is the prey. In general, users will find it easier to simulate the case of two technologies as the optimization engine converges quickly.

**Analysis of Phase – 4**

Phase 4 constitutes a very interesting case as 4 technologies are competing and all of them need to be considered. As explained in the previous chapter, music streaming is taking the market lead in the US and in the world while sales of either the digital format or the CD format are in decline. The analysis shows the following relationships:

- Paid Subscription – Music Downloads have a predator-prey relationship, where Paid Subscription is the predator. This finding doesn’t come with a surprise as streamed music and downloaded music live in the same medium such as consumers’ phones, computers, etc.
- Paid Subscription – On Demand Streaming has a competitive relationship. These two new technologies compete for market share. The simulation indicates that paid subscription has an advantage over on demand streaming.
- Paid Subscription – The CD has a predator-prey relationship where the CD is the predator. This indicates an interesting case and will be further investigated in the following part.
- Music Downloads – On Demand Streaming has a symbiotic relationship.
- Music Downloads – The CD has a predator-prey relationship where downloads is the predator.
- On Demand Streaming – The CD has a predator-prey relationship where On Demand Streaming is the predator.

**LV Coefficients**

<table>
<thead>
<tr>
<th></th>
<th>Download</th>
<th>On Demand Stream</th>
<th>CD</th>
<th>Paid Subscription</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>c</strong></td>
<td>Download</td>
<td>9.66E-05</td>
<td>8.05E-04</td>
<td>9.47E-06</td>
</tr>
<tr>
<td></td>
<td>On Demand Stream</td>
<td>2.89E-04</td>
<td>8.70E-04</td>
<td>2.58E-05</td>
</tr>
<tr>
<td></td>
<td>CD</td>
<td>6.09E-05</td>
<td>3.70E-04</td>
<td>3.14E-05</td>
</tr>
<tr>
<td></td>
<td>Paid Subscription</td>
<td>8.68E-05</td>
<td>6.85E-04</td>
<td>3.04E-05</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Download</th>
<th>On Demand Stream</th>
<th>CD</th>
<th>Paid Subscription</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>s</strong></td>
<td>Download</td>
<td>-1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>On Demand Stream</td>
<td>1</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>CD</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td>Paid Subscription</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Download</th>
<th>On Demand Stream</th>
<th>CD</th>
<th>Paid Subscription</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a</strong></td>
<td>Download</td>
<td>5.515E-01</td>
<td>4.739E-01</td>
<td>3.198E-05</td>
</tr>
</tbody>
</table>

Table 12 Model Parameters Phase-4

As far as we are aware, this analysis is one of very few cases where 4 technologies are used within LV modeling. As the optimization engine was tasked with finding 20 parameters, one can expect some level of computational errors in the model. However, given the current state of competition and the market capitalization of the companies in the business, the future of music streaming is the most sought after information. Our model shows that the model of paid subscription for streaming will take off where the other technologies in the model, except the CD, will lose market shares. The predator-prey relationship reported by the analysis for CD and Paid Subscription is
indeed an interesting one. This relationship yields revenue from CD sales to stabilize and should be closely observed.

![Figure 24 Phase-4 Analysis and Prediction](image)

**Conclusions of the Analysis**

This chapter has shown the emergence and transition of several product families and their simulation in the Lotka-Volterra model. It is shown that in most cases the LV model is able to determine the inherent relationships of emerging technologies with the incumbents in most of the cases. Without any doubt, each transition brings new challenges and opportunities. In the following part of the thesis, the results of the current transition will be discussed in detail.
Chapter 4 Conclusions and Discussions

In this chapter, major impacts of the service transition in the recorded music industry are discussed. It is argued that the transition did not only impact a limited number of stakeholders (artists, labels, etc.) but it changed the value chain in the industry, creating new major stakeholders and diminishing the power of some of the existing ones. The transition model is further examined with examples from content oriented industries as well as outside of content oriented industries. It is shown that the transition has limitations in some industries due to distinctive features in the existing products. The desktop publishing industry and printers are given as an example of where a similar transition is observed for the critical supply. The chapter ends with conclusions and further discussion of the model.

Learnings from the Music Industry

In the traditional music industry, record selling was the main source of revenue, hence the production and distribution of music was coordinated around this core activity. As a result, for a singer or song writer, finding a label to work with to produce and sell music records was extremely important. As mentioned in the earlier chapters, with the transition to streaming services, it is near impossible for an artist to make a living solely based on an income from the music he/she creates.

As a natural consequence of the transition, the leading source of revenue for singers is not album or single sales, but live demonstrations and tours. In 2013, all of the 10 artists who made the list of highest earning singers had more than 60% of their income from touring (Tschmuck, 2012). Following the shift of revenue sources, once a business of domestic markets, promotion and organization of concerts and tours have become a multi-billion-dollar industry, creating opportunities for new organizations such as Live Nation to thrive in. These dynamics changed the content of the agreements that artists made with labels. A new concept, 360 degree deals are made between musicians and labels that allow labels to not only collect income from record or digital music sales but also from artists’ concert income. As an example, in 2008, Jay-Z signed a
10 year $150 million agreement with Live Nation allowing the company to utilize revenue from touring, recording, and publishing\(^1\).

Another major impact of the transition is seen with the accessibility and availability of the music. As the world becomes increasingly connected with smartphones and internet access, music streaming services will continue to expand and reach more consumers. For instance, currently Spotify operates in 60 countries\(^2\). One can reasonably assume that every smartphone owner at some point will have access to at least one form of a free streaming service, meaning virtually everyone will have access to almost every song ever produced. Although this sounds like great news for musicians, wide accessibility brings a wide variety within itself. Spotify does not publish detailed statistics on the service such as the number of daily added songs, etc., but it is commonly believed that close to 20,000 new songs are added to the service daily and there are more than 30 million songs on the service, making it more difficult for new artists to be discovered.

Such wide availability introduces a fundamental question: Who will benefit from it? There is a debate among scholars, mostly around two ideas: One school of thought is the “long tail” theory (Anderson, 2006). In “The long tail: Why the future of business is selling less of more”, Anderson argued that with the improved ability for finding products closely tailored to their specific needs, consumers would migrate from popular products to custom ones. The other school of thought is mentioned in “The Winner Take-All Society” (Frank & Cook 1995). Frank and Cook argued that with broad communication and easy replication, consumers were more likely to converge in their habits and tastes. They raised the question of why consumers would use the second-best product when the best one was available at the same cost. Anita Elberse (Elberse, 2008) showed, with data from home-video and the music industries, that sales skewed towards the most popular titles, increasingly with digital content, supporting Frank and Cook’s ideas. With wide adaptation

of streaming services, one can expect popular artists to continuously take larger parts from the pie. An important idea to explain this phenomenon is the “paradox of choice” (Schwartz, 2004). According to Schwartz, the efforts needed to understand the available offers and to arrive at a reasonable conclusion are too overwhelming, that people either choose what they already know or follow the popular choice. As the number of choices increases with streaming, the effort to make a choice also increases.

**Examination of the Model**

In this section, the previously investigated transition in the music industry from physical products to digital products and to services is further investigated. It is shown that a similar transition has taken place in the home video industry, even though there are distinct differences between the two industries. The book publishing industry is another content based industry where a similar transition, though with significant limitations compared to the music and movie industries, took place. This industry was briefly investigated and the underlying reasons for the limitations of the transition are discussed.

A limited number of examples of the transitions that took place outside the content based industries are given. A new business model introduced by HP, creating a service transition in the desktop publishing industry is investigated, and a few examples of service transition from various industries are given. Benefits of the transitions to incumbents, competitive impacts of the model, potential “lock-in” affects, and opportunities and challenges for the new entrants as well as incumbents are discussed.

**Other Content Based Industries**

**Home Video Industry – A hybrid transition**

The home video industry has gone through a series of transitions, creating opportunities for new entrants and shaking the leadership of incumbents that are slow to respond to technological
advancements. Netflix, an American entertainment company founded in 1997\(^1\), can be placed at the center of the two latest transitions.

Movie rental in retail stores was a profitable and growing business in the 1980s. The number of movie rental stores increased from 7,000 in 1983 to 25,000 in 1986 (Hill et al., 2011). Blockbuster Video and Movie Gallery dominated the industry in the 1990s, utilizing VHS video cassettes. VHS stands for Video Home System and is the standard for analog video recording on tape cassettes.

In 1995 DVD format, a digital optical disc storage format, was invented, and by 1997, movies were also available on DVD. As shown in previous chapters, storage volume per minute has been on the decline in the music industry. A similar statement can be made here since a standard VHS cassette is around 31 cubical inches whereas a standard DVD is around 0.8 cubical inches.

Netflix founders took advantage of the newly invented smaller storage medium and started a mail order movie rental service through an online store. Blockbuster was hesitant to introduce mail order service with fears of cannibalizing its own retail stores and was late to adapt to DVD technology. The story ended sadly for managers at Blockbuster, who declared bankruptcy in 2010. Similar to the transition in the music industry, the transition in home videos brought changes in stakeholder networks. Netflix had two new major partners in its early years: The United States Postal Service, who was instrumental in shipping and receiving movies, as well as DVD player manufacturers such as Sony and Philips. In order to ensure the popularity of the DVD format, Netflix offered limited duration free membership to customers with DVD players (Osterwalder, 2010). Moreover, the home movie business went through another significant transition with the infusion of streaming technologies. As the data below shows, online streaming is the most dominant format for home movies and it is likely to continue to dominate the industry.

Number of Netflix Subscribers in Millions

Figure 25 Number of Netflix Subscribers in Millions
(Source: Illustrated from Netflix shareholder letters from 2001 to 2016)

Figure 26 Distribution of Movie and TV Rental Market Revenue in the United States from 2012 to 2016
(Source: Statista)
However, there are significant differences in the movie streaming and music streaming industries, from both the technical side and business side. From the technical side, streaming and storing movies are more difficult than working with songs. Movies require more bandwidth to stream. Streaming one hour of video from Netflix consumes 3 GB per hour for HD and 7 GB per hour for Ultra HD\(^1\), whereas streaming music from Spotify consumes 115 MB per hour. Netflix requires such a high bandwidth that at peak times, it accounts for one third of the consumer internet traffic in North America. In order to satisfy high bandwidth requirements, Netflix created its own content delivery network (CDN), Open Connect, and optimized the servers’ locations in the network on par with the demand\(^2\). The company had to develop its own custom hardware to support its own storage and streaming systems.

From the business perspective, Netflix is in a very highly competitive environment with content providers such as HBO as well as other streaming services such as Hulu and Now TV. Also, Amazon Prime Instant Video service applies a hybrid model where customers can watch movies that are part of the prime membership plan as a service included in their membership but they can also rent or purchase digital movies from Amazon, which are typically new and not available for streaming. Low barriers of entry and a highly competitive market drove Netflix and Amazon to create their own content in recent years.

**Book Publishing Industry - Limitations of the Transition**

Book publishing is another content based industry with a rich history. Although modern manufacturing has made it more efficient, easier, and cost effective to produce books, there haven’t been drastic changes or transitions in the architecture of the books, until the introduction of electronics books. Metrics for books for tablets and physical books can be introduced in a similar fashion to the previously introduced metrics here. Obviously, with digitization, one can fit an enormous number of books on the tablets which have similar physical volumes with books.

---


% of U.S. adults who say they have ___ in the previous 12 months

Figure 27 Distribution of Reading Preferences in U.S. Adults
(Source Nielsen)

Perhaps one could expect the book industry to go through a similar transition as the transition in the movie or music industries, but the data show otherwise. Although digitization for books started a long time ago, physical books are far away from disappearing. In fact, in a recent survey, more than 90% of college students said that they’d prefer reading physical books over electronics books. In addition, research shows that reading electronic books can negatively impact how the brain responds to the text, especially reducing reading attention, focus, and ability to maintain attention to detail (Wolf et al., 2008). As shown in the figure above, consumers continue to prefer printed books over e-books and audio books. Therefore, the case of printed books stands as a strong example – where as long as the old product has features to differentiate and make itself more attractive to the users, it would be immune to a complete service transition. It is important to add that there have been service transitions in some sub-segments of the industry. For instance, similar to music streaming services, several vendors such as Amazon’s Audible and Audiobooks offer monthly subscription models for their content.

Examples from Outside of the Content Based Industries

Service Transition on Critical Supplies – HP Instant Ink

Even though various services have been operating for many years that allow consumers to order print documents and to ship them or pick them up from the stores (Staples, FedEx, and various lower cost service firms), demand for personal printing supplies continue to be strong as customers need to have access to supplies for immediate printing. Launched in 2014, HP’s Instant Ink service introduced a new approach to printing, providing “printing as a service”\(^1\). In this model, consumers pay a monthly subscription fee that is determined by how many pages they expect to print in a month. Internet connection and embedded units in the printer allow HP servers to monitor the users’ behavior and estimate the amount of ink left in the printer. If the ink goes low, HP sends a new cartridge and a pre-paid envelope to return the empty cartridge to the subscribers before the ink completely runs out. HP claims to save costs drastically with the new service. Details for the subscription types and pricing for HP’s ink service are as shown in the image below.

![Image showing subscription types and pricing for HP Instant Ink](source.png)

*Figure 28 Instant Ink Subscription Types and Pricing (Source HP)*

This case is not a transition from physical products to pure services. However, by introducing newer functionalities into their printers to monitor and estimate the users’ behavior, HP has

---

created a new successful solution that provides ease to the user in various dimensions such as not having to worry about running low on their ink, or purchasing the right ink for their printer. The model has attracted more than 2 million subscribers in six countries so far. HP, its channel partners, and retailers continue to capture value from printer sales and HP continues to capture value from the ink sales. But with the introduction of printing as a service, HP now has a better channel for gathering information from its customers. For instance, HP now has better insights regarding the operational condition of the printer, and such information will be valuable in the next generation of product designs.

![Diagram of Core Product (Printer) and Essential Supply (Ink)](image)

**Figure 29 Instant Ink Service System**

**Other Examples of the Model**

One could call HP’s transition in printers as a hybrid transition since it entails both components of service and conventional product sales. Similar examples can be found in a wide range of industries. Michelin now offers a tire lease program where consumers can pay per mile for their tires\(^1\). Angaza operates solar energy panels with a pay-as-you-go model\(^2\). Philips Healthcare leases MRI machines and hospitals/clinics can select to pay per the scans that are printed. The Wall Street Journal and other prominent newspapers have websites and apps for which

---

2. [https://www.angaza.com/](https://www.angaza.com/) (Both links were accessed in April 2017)
customers can pay monthly subscription fees to access premium content. Online retailers such as Birchbox offer subscription services where customers access consumable products with monthly or quarterly subscription programs.

**Software Industry – Root of the Transition**

One could argue that the popularity of “as a service” model is rooted with all over the board adaptations in the software industry. Customizing software products to individual customer needs has become a core activity for the software business (Cusumano, 2004). The software industry has been undergoing a transformation, where the source of revenue is shifting from traditional product sales or license fees to services and subscription based software sales. In the 1990s, nearly all of the software companies were generating their revenues from selling upfront licenses. However, by 2007, nearly 50% of web based enterprise software vendors were charging monthly fees but not upfront license fees\(^1\). That same year, more than 50% of IBM’s total revenue came from its consulting services, including product implementation and support (Maglio at al., 2008). Scholars of the software industry argue that the software business has transformed from a product business to a service business (Cusumano, 2008).

**Discussions**

**Discussion on Characteristics of the Service Model**

The highlights of the transition from products to services are built on several benefits that come from the transition. With the service model, there is a stronger communication between the customer and the enterprise, resulting in a recurring relationship. The service model makes it very easy to sell new offerings and improvements. Once they establish a simple version of the service, customers have the option of adding vertical offerings to expand the benefits of the service. There is also a structure in place to extract customer insights directly. Typically, customers are continuously connected to the service system, allowing the enterprise to ask for feedback, monitor usage history, and better understand the interaction between the product

and customers. A deeper understanding of customer needs then allows for a more efficient market segmentation. Continuous connectivity allows valuable information, regarding the customers such as demographics and time of the consumption, to be known at all times. The service system allows continuous feedback from customers as to which vendors can take advantage to improve their products. In the service system, there is a central intelligence unit (cloud component) that can be easily updated without annoying the customer.

**Discussion on Technology Strategy**

Transitioning to a more service oriented model could eventually have all managers ask the most fundamental questions about their businesses: “What business is my company in?” Transition is changing the way that value is created and captured at various levels. Channel partners, retailers, suppliers, manufacturers, designers, and contractors will have to evaluate their core processes to be able to join the service momentum. The service model comes with unlimited questions and research potential regarding the value chain of incumbents and new entrants. Here, the main findings are only very briefly discussed, as the business model with its components in the service transition is a deep topic that could yield to another thesis.

Transitioning to a service system creates new opportunities to differentiate the products from competitors. Enterprises that move first to service systems will have the first access to consumer data, allowing them to better customize core offerings and to better segment their markets. One of the new differentiation mechanisms with services is that with the help of software, products could offer services that are customized at the individual level. Companies could add new features to existing, near commoditized appliances. A good example is Samsung’s WF457 washer machine which allows users to interface with the machine with their phones, adding a new layer of interactivity and connectivity into the use case (Porter & Heppelmann, 2014).

On the other hand, with the service transition, buyers gain advantages over enterprises. In a model where a consumer doesn’t have to pay any down payment but only a monthly subscription fee, switching from one service to another has a very low financial cost. Similarly, once the
products are commoditized and services are entirely or nearly exchangeable, consumers can quickly choose a vendor for another. Defense mechanisms are utilized by software as service vendors have many lessons to learn for new implementers of the service model. For instance, Dropbox, Inc., the company that operates Dropbox file hosting service, competes with super powers such as Google and Apple for the personal cloud based data storage market. The company took advantage of the network effects and grew substantially in the early years. Dropbox cannot compete with Google over cost but by reaching out to customers early and having them store their personal files in its servers, Dropbox made it difficult for its customers to switch to another service and created an advantage over its competitors.

Differentiating the offerings in services requires careful long term strategic planning. For instance, in movie streaming, content owners could partner with technology service firms and quickly start offering streaming services. This could be one of the motivations for both Netflix and Amazon to develop their own content. In fact, they have become so successful at it that in 2017, for the first time, streaming service companies won Oscars. Amazon won Best Original Screenplay, Best Actor, and Best Foreign Language film awards while Netflix won Best Documentary (Short Subject) award. Utilizing technologies from Akamai or Amazon Web Services and external technology consultancies, it is relatively easy to develop a streaming service in a very short time. Netflix’s activities toward developing their network and the hardware components could be perceived as a strategic move towards differentiation and reducing cost.

**Discussion on Pricing**

It is certain that pricing service systems require a holistic approach on the value chain, that is more sophisticated than the traditional, cost of the goods based pricing methods. However, there are many open questions on efficient pricing strategies in the modern service that are beyond this research. It is convenient to have a monthly subscription model as most vendors chose to

---

apply. Could there be other periods that are more ideal for both consumers and vendors? How should a new entrant price its service? How should the first service offering in an industry be priced? Efficient pricing for service systems could potentially yield another thesis. In this brief part, I share my findings for the most important aspects of pricing in service systems.

Pricing should be designed to allow vertical sales in a way that customers who need additional benefits, add-ons to products, and expansion from the core offering, can be provided with an accessible way to purchase them with proper pricing models. For instance, in the streaming video services, Amazon has a superior pricing strategy compared to Netflix. Amazon lets its prime members access a set of streaming videos (movies, TV shows, etc.) without an additional charge. However, if customers wish to watch the newest movies or old movies that are not included in the prime membership, Amazon lets them purchase or rent these movies with an additional fee. In comparison, Netflix only offers the membership option and customers are limited to the movies that Netflix has in the membership plan.

In service systems, flexibility carries a critical importance. It is important for new entrants who can seize opportunities to undercut incumbents with slightly cheaper offerings, and gain a wide consumer base. For example, had HP priced a per page cost for printing too high in its service model, a new entrant could easily offer a cheaper cost and enter the market. As mentioned in the previous paragraphs, utilizing data generated by consumers’ usage habits allow vendors to better segment their markets. Pricing should take full advantage of market segmentation. Flexibility in the pricing of service systems can allow entry to new and underserved markets, and especially to entry level customers. In SAAS business, it is already become a common practice to operate on the Freemium model to attract new developers to platforms. Although, it may not be possible for manufactured goods to be offered for free, the cost of entry should be kept as low as possible for broader access.

In a system where vendors can offer dozens of extras on top of the core offerings, simplicity is critically important. Instead of pricing each additional feature, SAAS vendors choose to bundle
their offerings into a few groups and assign a price to each group. Especially for the B2C business model, combining offerings into 2 or 3 bundles is the dominant strategy. However, for sophisticated users, SAAS vendors can price each service separately. For instance, for a coffee vendor who is trying a monthly subscription model, implementing the model with bundles instead of individual coffee offerings could make the pricing simpler and easier to choose.

Conclusions

Technological innovation brings structural changes
Our analysis reaffirmed that technological innovation is not limited only to replacing an old technology but it is a driving force to change economic structure and stakeholder relationships, as it has been pointed out by many prominent scholars. Our research showed that with streaming services, new business models emerged, the revenue structures changed and the value network among the stakeholders changed drastically.

Partnerships and collaboration are essential in services
We noted that despite their decades of experiences, music giants failed in their attempts to dominate the internet based streaming services. This was mostly due to the limited offerings, poor user interfaces and poor architectural choices. In contrast, Apple achieved enormous success by following a more collaborative strategy making its iTunes software available on Windows and offering music from all major labels.

Modular architectures are at the center of service systems
Cloud computing is the major underlying technology for the successful diffusion of services. The physical blocks of cloud computing systems, data centers are built with standardized hardware utilizing modular architectures. Modular architectures make superior scalability, rapid growth and quick hardware replacements possible. On the software side, Service Oriented Architecture, the paradigm behind successful implementation of services like Spotify, is essentially an abstract interpretation of the modular architecture.
Service models can create lock-in effects

Arthur (Arthur, 1989) investigated increasing returns to adaptation and positive feedbacks for technology adoption. He pointed that the more a technology is adopted, the more likely it is to be further adopted. He argued that, these could lead to “lock-in” of incumbent technologies and prevent acceptance of superior alternatives. Service model can create such lock-in effects and defense mechanisms for incumbents over technologically superior alternatives. The tire industry and Michelin’s service model can be given as an example to further explain the argument. The lifespan of tires has improved substantially over the last century. If, in the future, a tire manufacturer introduces new tires that are extremely reliable that consumers only need to purchase once over the lifetime of their vehicles, Michelin’s service model (as mentioned previously, charging customers per mile) could set a defense mechanism for the company. Customers could be reluctant to pay high upfront costs to acquire the new tires with advanced technology and Michelin can offer new services or to keep their existing tires popular, while justifying the investments to the new reliable tire technology.

Nature of interactions change overtime with a pattern

Our analysis showed phases of interactions between technologies and product families. We observed that when a new technology entered the market, it could have a symbiotic relationship with the incumbent and the relationship tended to change to predator / prey and to competition over the life-cycle. For instance, after Apple entered to the streaming music market with Apple Music, number of paid subscribers continued to increase for Spotify. After reading our analysis in the previous chapters, one could easily notice the symbiotic interactions and can be sure that these interactions will change over time.

With the service transition, most of the innovation occurs in the software domain

In the service model, sophisticated sensors make it possible to obtain information regarding the products and the products’ operational environment. Embedded computers built into products allow them to connect to the central computing architectures, and analytical software services along with cloud based micro services carry an increasing importance as they make rapid
deployment of new services possible. Enterprises find themselves in a broader ecosystem of vendors now. HP’s printers now have cloud connection, a microcomputer, firmware to run the computer, LCD screen, and an operation system to interact with the user and more. Change in the vendor ecosystem moves almost all the customization to the software and service domain, changing the traditional dynamics in the supplier relationships (Porter & Heppelmann, 2015).

**Service model introduces new dynamics to the competition between incumbents and new entrants**

If an incumbent can master agile methods, continuously introduce new services, create new ways to develop insights from user data, and develop product architectures that can offer new services without any hardware upgrades or modifications, then the incumbent can achieve a significant advantage over new entrants as with the product superiority along with network effects, monetary, and non-monetary switching costs that would increase substantially. In addition, incumbents with a large product portfolio gain an advantage over new entrants as they can divide investments needed for a service transition over their portfolio. For instance, if a vendor of industrial washer machines develops capabilities to add an operation system and user interactivity features to its products, presumably one team would be tasked with developing the core engineering functions, and smaller teams would work to customize the features for different products. On the other hand, if incumbents cannot create and capture value from connectivity, interactivity, and machine intelligence, then the new entrants could make the incumbents’ offerings less relevant. Apple’s iPhone made MP3 players, portable game consoles, personal video players, voice recorders, and GPS navigation devices somewhat obsolete. Currently, Apple, Google, and Amazon are aiming for control over appliances in the form of smart homes. Home appliance manufacturers should develop strategies to be part of the smart home ecosystems or they face commoditization and irrelevance.

**Product differentiation is a matter of survival**

Our simulations with Lotka-Volterra model reinforced Darwin’s view on the competition: two interchangeable technologies cannot stay in competition forever; one of them would become
extinct. Therefore, companies need to find ways to differentiate their offerings to survive. On the other hand, as cloud technologies and hardware products converge in their capabilities, subtle differences make tremendous impact on the success of a company. A slight disadvantage in user interface can run a company out of business or incremental improvements in prediction algorithms can create a strong competitive advantage. Hence the source of the differentiation, innovative human resources are at the center of the transition.
References


Utterback, James. "Mastering the dynamics of innovation: how companies can seize opportunities in the face of technological change." (1994).


APPENDIX

Matlab Codes

Instructions
User needs to create a data input following the music input, example given below in MusicDataInput.m. After data is provided, LVOrganizer runs the simulation. Software requires Matlab and Optimization Toolbox Licenses to run. All the files below are available at https://github.com/yilmazerd/LVM

%LVTime.m
%Also available at https://github.com/yilmazerd/LVM

```matlab
function Tout=LVTime(s,c,a,T0,years);

Tbuffer=zeros(length(a),years+1);
Tbuffer(:,1)=T0;

for ind=1:length(Tbuffer)
    T=Tbuffer(:,ind);
    scprod=s.*c;
    scale=(exp(a)-1)./a;
    den=1-(scprod*T).*scale;
    num=exp(a).*T;
    Tbuffer(:,ind+1)=num./den;
end

Tout=Tbuffer;
disp(Tout');
%End of LVTime.m
```
%LVSolution.m
%Also available at https://github.com/yilmazerd/LVM
[p k] = size(Data);

a_lowest = rand(p,1);
s_lowest = ones(p,p) - rand(p,p)*2;
c_lowest = rand(p,p)/10;
sum_lowest = 1e9;

for i = 1:iterations,
a = rand(p,1);
s = ones(p,p) - rand(p,p)*2;
c = rand(p,p)/10;
[sout,cout,aout] = LVoptimize(Data, true, a, s, c);

T0=Data(:,1);
Tout=LVTime(sout,cout,aout,T0,lastyear-firstyear-1);
yr=firstyear:1:lastyear;

disp('Total sum of squares')
sumsq = sum(sum((Data(1:end,2:end) - Tout(1:p,2:k)).^2))/((p-1)*k);

if (sumsq<sum_lowest)
    sum_lowest = sumsq;
a_lowest = aout;
s_lowest = sout;
c_lowest = cout;
end

end

aout = a_lowest;
sout = s_lowest;
cout = c_lowest;
%End of LVSolution.m
%LVOrganizer.m
%THIS IS THE SCRIPT TO RUN
%Modify data input script as necessary
%All the most recent files can be found at https://github.com/yilmazerd/LVM
%LVDataInput
MusicDataInput
LVSolution
LVVisual

disp('****Optimum LV Parameters****')
disp('c matrix')
disp(cout)
disp('s matrix')
disp(sout)
disp('a vector')
disp(aout)

hold on
hold on
legend('Download Simulation','Download Data','On Demand Simulation','On Demand Data','CD Simulation','CD Data','Paid Subscription Simulation','Paid Subscription Data')

Data = [V;C;T];
%End of LVOrganizer.m
%LVoptimize.m
%Also available at https://github.com/yilmazerd/LVM
function [s,c,a]=LVoptimize(T,LIM,a,s,c,sc_Ue,sc_Le)
%[sout,cout,aout]=LVopt(T,LIM,a,s,c)
%Erdem Yilmaz - Chris Aden

% T=T[m,n] is a technology matrix containing m technology rows specified
% LIM: boolean: true-use simple constraints on parameters, false-unconstrained
% minimization
% s=initialized correlation matrix
% c=initialized dependencies matrix
% a=initialized growth vector

[m,n]=size(T);
scale=1e0; %optimization scalar
sc_U=ones(m^2,1);
sc_L=-1*ones(m^2,1);
[e d]=size(sc_U);
zerosforp=zeros(1,sqrt(e));
for i=1:sqrt(e),
    zerosforp(i)=1+(i-1)*(sqrt(e)+1);
end
clear e d zerosforp

if nargin==2;
a_init=ones(m,1);
sc_init=zeros(m);
elseif nargin==3 & length(a)==m;
a_init=a;
sc_init=zeros(m);
elseif nargin==4 & length(a)==m;
a_init=a;
sc_init=s;
elseif nargin==5 & length(a)==m & isequal(size(s),size(ones(m)));
a_init=a;
sc_mat=s.*c;
sc_mat=cell2mat(sc_mat);
sc_init=cell2mat(s);
scale=1/min(abs(sc_init));
sc_init=sc_init*scale;
elseif nargin==7 & length(a)==m & isequal(size(s),size(ones(m)));
a_init=a;
sc_mat=s.*c;
sc_mat=cell2mat(sc_mat);
sc_init=cell2mat(s);
scale=1/min(abs(sc_init));
scale=1/min(abs(sc_init));
if LIM==true
    sc_U=cell2mat(sc_Ue);
    sc_L=cell2mat(sc_Le);
end
end

x_init=[sc_init(:);a_init]';
if LIM==true
    a_U=ones(m,1)*100;
a_L=ones(m,1)*0;
    U=[sc_U;a_U].';
    L=[sc_L;a_L].';
elseif LIM==false
    U=[];
    L=[];
else
    error('Constraint variable is not understood.');
end

tolx=le-8;
tolf=le-8;
iter=100;
funeval=le5;

options=optimset('TolX',tolx,'TolFun',tolf,'MaxIter',iter,'Jacobian','on','display','iter',
    'MaxFunEvals',funeval,'DerivativeCheck','off');

x=lsqnonlin('LVcompute',x_init,L,U,options,T,m,n,scale);

x=x.';
scd=x(1:m^2);
sc=ones(m);
sc(:)=scd;
s=sign(sc);
a=x(m^2+1:m^2+m);
s=sign(sc);
c=s.*sc/scale;
%End of LVoptimize.m
function [Err,Jake]=LVcompute(x,Tmeas,row,col,scale,fig1,fig2);
% Erdem Yilmaz - Chris Aden

x=x.';
Tmod=zeros(row,col);

% For Gradient based
C=x(1:row^2);
Cmat=zeros(row);
Cmat(:)=C/scale;
Cmat=Cmat.';
A=x(row^2+1:length(x));
EA=diag(exp(A),0);
INA=diag(1./A,0);
EAml=EA-eye(row);
Tmod(:,1)=Tmeas(:,1);
for ind=2:col
    TO=Tmod(:,ind-1);
    num=EA*TO;
    den=ones(row,1)-INA*EAml*Cmat*TO;
    Tmod(:,ind)=num./den;
end
ErrM=(Tmod(:,2:col)-Tmeas(:,2:col))./Tmeas(:,2:col);
Err=ErrM(:);

xvars=row+row^2;
dC=zeros(row,row);
JT=zeros(row,xvars);
DTbuffer=zeros(row,xvars);
dparam=zeros(xvars,1);
dparam(1)=1/scale;
Jake=zeros(row*(col-1),xvars);
for per=2:col
    T=Tmod(:,per-1);
    dTmod=DTbuffer;
    for ii=1:row
        Tii=T(ii);
        dTii=dTmod(ii,:);
        Aii=A(ii);
        N=exp(Aii)*Tii;
        D=1-(dot(Cmat(ii,:),T)*(exp(Aii)-1)/Aii);
        X=(exp(Aii)-1)/Aii;
        for jj=1:xvars
            dC(:,jj)=dparam(1:row^2);
            dC=dC.';
            dTiijj=dTii(jj);
            dTjj=dTmod(:,jj);
            if(jj==ii+row^2)
                dAi_dp=1;
                dXi_left_dp=1/
                Aii*(exp(Aii)-1)/(Aii)^2;
            else
                dAi_dp=0;
                dXi_left_dp=0;
            end
        end
    end
end
dNij_dp = \exp(Aii) dTijjj + Tii \exp(Aii) dAi_dp;

\begin{align*}
\frac{dDij_dp}{dNij_dp} &= 1^* (dXij_dp \cdot \text{dot}(Cmat(ii,:), T) + X \cdot (\text{dot}(dC(ii,:), T) + \text{dot}(Cmat(ii,:), dTjj)));
\end{align*}

J{T}(ii,jj) = (1/D \cdot dNij_dp - N/D^2 \cdot dDij_dp);

\begin{align*}
\text{JTnorm}(ii,jj) &= \frac{JT(ii,jj)}{Tmeas(ii,per)};
\end{align*}

\begin{align*}
\text{JTnorm}(ii,jj) &= JT(ii,jj); \\
\text{dparam} &= \text{circshift}(\text{dparam}, 1);
\end{align*}

end

end

dTbuffer = JT;

ji = per-1;

\text{Jake}((ji-1) \cdot \text{row}+1:ji \cdot \text{row},1:xvars) = JTnorm;
end

% End of LVcompute.m
%MusicDataInput.m
%Also available at https://github.com/yilmazerd/LVM
%THIS FILE MANIPULATES THE DATA INPUT
%Deals with music simulations, follow the instructions to use for any data
%Download data file from
%https://github.com/yilmazerd/LVM/blob/master/musicdata.mat

clear all;
clear all;
close all;

% This section deals with loading data, modify as needed
load musicdata.mat

msize = 10; % how many years is imported from data to the model
STARTdelta=34; % starting year, 1 means 1973
pyears = 1; % prediction years
iterations = 200; % how many iterations in the simulation

% This section deals with modifying data, change as needed
Vl=LPEP+VinylSingle; % Vinyl data is combined for full album and singles
V = Vl(STARTdelta:msize+STARTdelta-1)+rand(1,msize);
C = Casette(STARTdelta:msize+STARTdelta-1)+rand(1,msize);
T = Track 8(STARTdelta:msize+STARTdelta-1)+rand(1,msize);
C2 = CD(STARTdelta:msize+STARTdelta-1)+rand(1,msize);
PS = PaidSubscriptions(STARTdelta:msize+STARTdelta-1)+rand(1,msize);
DAp = DownloadAlbum(STARTdelta:msize+STARTdelta-1)+rand(1,msize);
DSP = DownloadSingle(STARTdelta:msize+STARTdelta-1)+rand(1,msize);
DA = DSP + DAp;
OD = OnDemandStreaming(STARTdelta:msize+STARTdelta-1)+rand(1,msize);

firstyear = 1972+STARTdelta;
lastyear = firstyear+msize+pyears;

Data = [DA;OD;C2;PS];

% End of MusicDataInput.m