Digital Fluency

Understanding the Basics of Artificial Intelligence, Blockchain Technology, Quantum Computing, and Their Applications for Digital Transformation

Volker Lang

Apress®

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To my family and friends.

Advance Praise for Digital Fluency

"If you are trying to make your organization fit for the 21st century, *Digital Fluency* is your ultimate guide. Enriched with numerous practical examples, valuable summaries and actionable frameworks, it provides an accessible and comprehensive introduction to the most exciting digital technologies of our time. Whether you are a business leader, start-up entrepreneur, policy maker or student, *Digital Fluency* gives you everything you need to get ready for the exciting digital future that lies ahead of us."

— Rasmus Rothe, Founder of Merantix AG

"In a tech world that is increasingly dominated by buzzwords, *Digital Fluency* will provide you with the necessary theoretical and practical background to make sense of digital key technologies like artificial intelligence, blockchain, and quantum computing. It will give today's business leaders a head start and is a top-priority read for anyone seeking to reshape our future by leveraging digital technologies."

— Jean-Luc Scherer, CEO and Founder of Innoopolis

"At the dawn of the 4th industrial revolution, Volker Lang provides us with a forward-looking masterpiece that makes us all feel comfortable about the digital future. In *Digital Fluency*, students and professionals on the technical and business side will find valuable advice that will guide them on their transformative journey to their rightful place in the growing digital world. If you want to understand how artificial intelligence, blockchain and quantum computing continue to augment the human experience, then this excellent guidebook is for you."

— Greg Coquillo, LinkedIn 2020 Top Voice for AI and Data Science

"By focusing on artificial intelligence, blockchain, quantum computing and their real-world applications, Volker Lang has written an immediately accessible book which will equip employees and leaders of businesses alike with the requisite confidence to effect digital transformations. I cannot recommend reading *Digital Fluency* enough."

— Vincent Anandraj, Managing Partner at Mynah Partners Ltd.

"Digitization and digital transformation are the central topics of the 21st century. In his book, Volker Lang creates a fundamental understanding of the most important digital technologies and comprehensively describes their impact on industries and society. In the end, it becomes clear that no one can escape the future, but we all have an opportunity and obligation to shape it. A book for everyone seeking orientation in the digital age."

— Christoph Bornschein, CEO and Founder of TLGG

"*Digital Fluency* is an excellent introduction to future technologies beyond just buzzwords. Filled with numerous practical applications of digital technologies to your own line of work, it is highly recommended for all aspiring disruptors from students to seasoned executives."

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"As an industry, we have managed to transition artificial intelligence (AI) from 'research' to a technology that is part of the lives of countless people around the world. And that is just the beginning! *Digital Fluency* provides excellent examples of how enterprises have embraced AI in a meaningful way."

— Ewa Dürr, Head of Product Strategy & Operations, Google Cloud Artificial Intelligence

"Blockchain will, like no other technology, shape the years from 2020 to 2030. But it unfolds its true capabilities only in combination with other technologies. *Digital Fluency* provides an insightful introduction to exactly these key technologies constantly reshaping our world and presents a comprehensive overview of their potential applications. It promotes new digital thinking, skillfully inspires new applications and is therefore a compelling read for any leader."

— Philipp Sandner, Professor at Frankfurt School of Finance & Management and Head of Frankfurt School Blockchain Center (FSBC)

"Volker Lang describes the most relevant cutting-edge technologies for solving the critical issues of our time in a clear and well-structured way, so that readers can contextualize and apply them within their own business activities. *Digital Fluency* is a compelling guide to digital value creation for investors, entrepreneurs and professionals of private and public organizations."

— Alessandra Sollberger, Founder of Top Tier Impact (TTI) and Technology Investor

"Digital technologies have shaped the past fifty years and new emerging digital technologies promise to shape our future. For example, quantum computers are moving out of physics labs – they have reached a maturity in size and performance that puts them on the cusp of being able to beat conventional supercomputers in solving problems that matter. *Digital Fluency* presents a bang up-to-date perspective of the quantum computing industry today, from the quantum chips currently available on the cloud to the most exciting business applications being explored."

— John Morton, Professor of Nanoelectronics & Nanophotonics at University College London (UCL)

"With great clarity and pragmatism, Volker Lang explains the key concepts and buzzwords of digital economy in an entertaining way and uses numerous examples to inspire new applications, products and services in a variety of industries, including banking and finance. *Digital Fluency* is an excellent introduction to the most important digital topics of our time and an essential reading for anyone looking for guidance in the digital world we live in."

— Laure Frank, Head of Digitalization at Raiffeisen Switzerland

"*Digital Fluency* is a delightful guide full of important information for those interested in emerging technologies that enable the digital transformation of organizations. Volker Lang offers a very easily accessible overview of the most important digital technologies and gives companies valuable recommendations and tools for completing their digital transformation successfully."

— Angeliki Dedopoulou, EU Public Affairs Senior Manager, Huawei Technologies

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About the Author

Dr. Volker Lang is an experienced digitalization expert with profound expertise and great enthusiasm for artificial intelligence, blockchain technology, quantum computing, and their applications for digital transformation. As a senior project manager and former management and strategy consultant working with Volkswagen Group, he has been leading various large-scale business transformations with focus on electrification, digitalization, and other future trends.

Volker is a trained quantum physicist as well as holds a doctorate from Oxford University and diploma in physics and nanotechnology from Ludwig-Maximilians-University of Munich. He has attended the Oxford Blockchain Strategy Program at Saïd Business School, Disruptive Strategy at Harvard Business School, as well as the well-known Machine Learning program at Stanford University among other interdisciplinary trainings for business executives. His achievements were recognized by prestigious scholarships and international prizes, such as by Trinity College Oxford, the Engineering and Physical Sciences Research Council, German Physical Society, and Konrad-Adenauer-Stiftung.

You can reach Volker on LinkedIn (www.linkedin.com/in/dr-volker-lang) and his digital innovation consulting services on www.DInnovators.com.

Introduction

Digitalization and digital transformation, big data and artificial intelligence, as well as quantum computing and blockchain technology are among the hottest and most cited buzzwords in media today. Everybody has heard about them, but only few people comprehend them. Metaphorically speaking, they seem to occupy a high-speed train that departs soon. Nobody knows wherefrom and whereto, but everybody likes to join immediately so as not to lose a chance. Hence, digital technologies have been subject to intense speculation and controversial discussions in politics, industry, and society that are driven by exaggerated hopes and fears. Optimists highlight the great future prospects of digital technologies and envision the arrival of new very practical applications that create even more jobs than digitalization destroys. Pessimistic people, on the other hand, spread fears about them and are afraid of mass unemployment caused by intelligent and often violent robots that transcend human intelligence and thereby render millions of jobs obsolete.

Independently of which party has the better arguments, both sides do generally agree that digital technologies continue to have tremendous social and economic impacts. Just think about the Internet and smartphone that radically changed the way we communicate, inform, interact, and transact with each other. The smartphone, for example, evolved from being simply a better phone to a digital platform for mobile applications that provide access to the Internet and soon became indispensable in our everyday life. With the arrival of digital technologies and the smartphone, in particular, the amount of readily available information and data exploded. Thus far, we have seen the most prominent effects in industries like retail, advertising, media, and music, but others are poised to follow. Google, for example, processes more than 40,000 searches every second. Users of YouTube watch more than 68,000 videos and send over 5,800 tweets on Twitter every second. Inspired by this breathtaking scale, Google's chief economist Hal Varian once noted in 2013 nicely: "A billion hours ago, modern *Homo sapiens* emerged. A billion minutes ago, Christianity began. A billion seconds ago, the IBM personal computer was released. A billion Google searches ago... was this morning."[1] With an average usage of 28 minutes per day and more than 8.9 million daily uploads of novel photos and videos, the social networking service Instagram is another example, which impressively demonstrates how the Internet, smartphones, and

[1] See https://behavioralscientist.org/when-google-speaks-people-listenand-they-should-a-review-of-work-rules/.

other digital devices have revolutionized the way we consume information. News is no longer read in printed newspapers and magazines but rather through online media platforms and social networks like Facebook, which completely disrupted the business of established media and news publishing companies. Amazon, Alibaba, Microsoft, Netflix, and Spotify are just a few examples of companies that explored and picked up this digital trend early on and leveraged digital technologies successfully to disrupt existing and create new, highly profitable digital revenue streams.

We are also seeing the beginning of digital transformation in the financial services industry today, where established investment banks and hundreds of fintech startups – backed by billions of US dollars in venture capital – employ a whole range of digital technologies to advance their products and services. They optimize financial value chains and pricing models by quantum computers, offer easy-to-use retail banking and payment services powered by blockchain technology, and increase cybersecurity by artificial intelligence as you will see in selected examples throughout this book.

Accelerated by the severe corona crisis caused by the deadly COVID-19 virus spread in 2020/21 worldwide, digital transformation has also begun to disrupt the economically very important automobile industry. We may see the arrival of, for example, autonomous vehicles powered by artificial intelligence, fully connected vehicle infotainment services with in-car payment systems based on blockchain technology, and navigational systems that identify the fastest route through overcrowded cities by leveraging quantum computing embedded in a mobility cloud infrastructure in the not too distant future. The digital transformation of the automotive industry is expected to improve customer journeys by new functionalities and drive gigantic gains in productivity, efficiency, and cost savings, which is why it is a matter of time until it sweeps across every sector of modern industry and society.

No discussion about digital transformation would be complete without mentioning its wide-ranging impact on governmental organizations, too, such as central banks, tax offices, national courts, notary services, and health departments. Digital transformation does not only help private organizations to streamline internal processes but also public institutions to reduce bureaucracy and optimize public product and service portfolios. There is no doubt that organizations – private as well as public – that embrace digital technologies today will determine their competitive stance for the decades to come.

Digital Fluency is meant to be an introductory handbook for employees and decision makers in private and public organizations, who want to understand digital technologies and apply them in their own ecosystem. It therefore makes a broad attempt at synthesizing key concepts and bringing together the most important technologies that foster digital transformation in organiza-

tions today. You will see throughout this book that quantum computing, blockchain technology, and artificial intelligence are the most important digital technologies as they can be applied to a large variety of use cases across all sectors of modern industry and society.

But what are digital technologies about, and how do they operate? How can we apply them in our job and everyday life? How can we use them to optimize existing and create new, valuable opportunities? What are the most prominent use cases of quantum computing, blockchain technology, and artificial intelligence, and when do they make sense? What are the advantages and disadvantages compared to existing technologies, and what are the limitations and challenges involved in leveraging them? *Digital Fluency* answers all top-of-mind questions you may have about digitalization and digital technologies. The answers will allow you to develop a profound understanding of them as an important prerequisite for accessing their impact on your own professional ecosystem and preparing yourself for the exciting digital future ahead of us. After reading this book, you will be able to better understand digital technologies, critically scrutinize daily news about them, and – most importantly – access their relevance and impact on your own life and professional career.

If you are a business leader, *Digital Fluency* provides you with a deep understanding of digital technologies and their impact on management and decision making. If you are a student, this book gives you different technology frameworks for thinking about the evolution of jobs and professional careers in digital industries. If you are a financial analyst or venture capitalist, *Digital Fluency* offers inspiring insights for developing and implementing highly profitable investment strategies. If you are a politician or policy maker, on the other hand, you will better understand how digital technologies will impact society and governmental organizations and how they can be used to simplify administrative processes, in particular. As a general reader, who does not fall into either of those categories, you will be surprised about how digital technologies impact modern industry and society and how they will shape our future as individuals in an increasingly globalized, fully connected, and highly digitized world.

As you read this book, you will realize that the history of digital transformation and digital technologies is a joyful and entertaining journey through a large range of academic disciplines including economics, behavioral science, information technology, natural sciences, and physics. This is why I will introduce you to some of the most fundamental and fascinating concepts of modern science in the following chapters without requiring any math skills that go beyond your junior high school classes.

Digital Fluency is organized into five chapters to cover scientific key concepts and highlight important applications exemplarily. Here is a brief description of each chapter:

- *Chapter 1, "Digitalization and Digital Transformation"*: This chapter provides you with the basics of digitalization and digital transformation. You will learn that both concepts arise due to the confluence of different digital technologies, such as quantum computing, blockchain technology, and artificial intelligence, that are profoundly disruptive in their nature. Furthermore, we will investigate the digital ecosystem of organizations and therein identify the most important driving forces of digital transformation, such as sustainability, cybersecurity, as well as the increasing complexity and connectivity of products and services. We will also take a look at digital transformation strategy including the innovation models of Amazon, Google, Microsoft, and IBM to highlight that digital transformation is much more than a simple update of an organization's IT infrastructure. Popular examples from Nokia and Kodak Eastman Company will illustrate the fatal consequences of digital disruption, a competitive force that often causes incumbent organizations to fail if they do not leverage digital technologies on time. This chapter concludes with a brief introduction to classical information processing that forms the basis for the operation of modern computers, smartphones, and other digital devices we use in our everyday life.
- *Chapter 2, "Quantum Computing"*: You will learn key concepts of quantum computing in this chapter, one of the most exciting and technologically most challenging digital technologies. Quantum computers are sometimes described as the "next level of supercomputing" since they can conduct gazillions of calculations simultaneously to offer exponential gains in computational speed and performance compared to traditional computers. This dramatic increase is related to different quantum effects, such as superposition and entanglement, that are used to encode and process quantum information. We will also cover the foremost important physical implementation schemes and fundamental types of quantum computers that are often incorrectly used in media alike. Besides this, there will be an introduction to the most relevant quantum computers that are commercially available

today, such as D-Wave's quantum annealer named 5000Q and Google's legendary Sycamore quantum processor. The latter attracted great attention in media lately when Google demonstrated quantum supremacy in 2019 for the very first time, an important technological milestone in the development of quantum computers. Last but not least, there will be a discussion of the most significant applications, such as drug development, financial portfolio optimization, and quantum machine learning.

- *Chapter 3, "Blockchain Technology":* In this chapter, we will take a look at blockchain technology, which was initially created for Bitcoin, the first worldwide and most popular digital money or cryptocurrency until now. You will learn that blockchain technology – the "ultimate trust machine" as it is sometimes called – deploys trust in untrusted environments. It thereby enables the trustworthy exchange of value between two or more transacting parties even if they neither know nor trust each other. You may be surprised to learn that value in this context may refer to any kind of valuable digital information, such as digital money, intellectual property rights, and other digitized assets. A vivid explanation of the most important key concepts, including peer-to-peer computer networks, digital signatures, and Merkle trees, will also allow you to better understand the overall Bitcoin transaction life cycle for transferring monetary value. Furthermore, we will cover smart contracts as an important extension of blockchain technology, which allows for automating administrative processes in organizations. While most experts agree that Bitcoin was a hype, we will see at the end of this chapter that applications of blockchain technology continue to grow. For this purpose, we will discuss the most important applications, such as international trade platforms, supply chain management systems, as well as etaxation and evoting.
- *Chapter 4, "Artificial Intelligence"*: In this chapter you will develop a basic understanding of artificial intelligence, the most versatile digital technology that fosters digital transformation. After studying its exciting history including IBM's legendary research projects named IBM Deep Blue and Watson, we will turn our focus to the different subcategories and learning strategies that are employed in state-of-the-art applications today. In this context, you will learn about supervised, unsupervised, and reinforce-

ment learning. You will also learn about the similarities between our human brain and artificial neural networks that emulate aspects of human intelligence by software and are at the heart of the emerging and increasingly popular field of deep learning. There is also coverage of the most important subcategories of artificial neural networks including recommender systems as well as convolutional, recurrent, and generative adversarial neural networks. Last but not least, we will have a close look at important and equally inspiring applications of artificial intelligence, such as Amazon's Just Walk Out shopping technology, Tesla's and Waymo's autonomous driving systems, Apple's Siri virtual assistant, Google's natural language processing and translation system, Benevolent AI's approach to drug development, Bloomberg's news analytics platform, JPMorgan Chase's intelligent pricing algorithm, as well as BlackRock's sophisticated investment network named "Aladdin".

- *Chapter 5, "Your Digital Action Plan"*: Time to get ready for your own digital transformation. This final chapter ties off our broad discussion of digital transformation and enabling technologies and provides you with an actionable and comprehensive framework for planning and executing your own digital transformation based on eight core dimensions. Peppered with numerous examples of very successful and world-leading organizations, we will particularly talk about developing digital business and operating models, selecting an appropriate technology stack based on cloud computing, and digitizing the core of an organization. You will also learn how to identify promising digital pilot projects, empower management and employees, and shape the organizational structure. Last but not least, we will highlight the importance of establishing an open innovation culture and leveraging your ecosystem by engaging with customers and other important beneficiaries.

In addition to a further reading section, you will find a summary of key points at the end of each chapter. Furthermore, Chapters 2, 3, and 4 will provide you with easy-to-use frameworks that will allow you to determine whether a digital technology can be applied to your own ideas and use cases or not. A comprehensive glossary of common terms related to digital transformation and digital technologies at the back of this book will provide further guidance on your own digital transformation journey.

From the large number of references in this book, you may deduce rightfully that quantum computing, blockchain technology, and artificial intelligence are very dynamic areas with new discoveries and players appearing on an almost daily basis. Although the numerous examples discussed in this book will surely become dated, the presented concepts, underlying principles, and frameworks will not. Those valuable insights will continue to apply as digital technologies improve and evolve over time.

Due to the great variety of digital topics covered, *Digital Fluency* allows for three different fast track learning journeys. If you are particularly interested in learning about digitalization and digital transformation from a business point of view, you may prefer to read selected sections of Chapters 1 and 5 only. If you have a very strong technological focus and want to better understand either quantum computing, blockchain technology, or artificial intelligence, you may like to read selected sections of Chapters 1 to 4 only. If you are familiar with digital transformation and the operational principles of its enabling technologies, on the other hand, I recommend reading the application sections of Chapters 2, 3, and 4 according to the following table.

I. Transformation Focus	II. Technology Focus	III. Application Focus
■ Sections 1.1 to 1.3	■ Section 1.4	■ Sections 2.3 to 2.5
■ Sections 5.1 to 5.9	■ Sections 2.1 and 2.2	■ Sections 3.3 to 3.5
	■ Sections 3.1 and 3.2	■ Sections 4.4 to 4.6
	■ Sections 4.1 to 4.3	

Finally, I wish you an enjoyable and entertaining digital journey through three of the most fascinating digital technologies of our time and their exciting applications and use cases in industry, politics, and society. I hope *Digital Fluency* will transform your thinking from an opaque landscape dominated by incomprehensible buzzwords to a place of digital inspiration for innovative projects and novel ideas.

Get inspired and enjoy reading.

CHAPTER

1

Digitalization and Digital Transformation

Digitalization is a technological trend that is reshaping all sectors of our industry and society today. It is considered a major and inexorable driving force of innovation and disruption that challenges private and public organizations equally. With all economic and societal sectors being affected, digital economy is very dynamic and increasingly competitive. It empowers new startup ventures – backed by many billion dollars of venture capital – to create novel value propositions by leveraging digital technologies. Their highly scalable, data-driven, and software-centric operating models increasingly collide with incumbent companies and poise an existential threat to their business. Just think about Apple's iOS and Google's Android smartphones, for example. Built on a consistent digital platform, both companies attracted ever-expanding ecosystems of third-party app developers that ultimately caused Nokia to tumble from a position of phone industry dominance into irrelevance. This story is threatening to repeat everywhere across the economy: The cloud computing services of Amazon, Microsoft, and Google are challenging traditional software and hardware providers, the online marketplaces of Amazon and Alibaba are replacing traditional retailers and challenge companies like

V. Lang, *Digital Fluency*, https://doi.org/10.1007/978-1-4842-6774-5_1

on-demand Walmart, and the video delivery services of Netflix and Hulu are about to disrupt traditional pay TV providers. Another very popular example is the online booking platforms Airbnb and Booking.com that leverage digital technologies to simplify booking and offer personalized and individually tailored travel experiences while disrupting the business of traditional hotel chains including Marriott, Hilton, and Hyatt. In order to capture the benefits of digital technologies, established organizations – independently of whether they operate in the public or private sector – are forced to incorporate them into their own ecosystem to advance their product and service portfolios through an organizational change process that is commonly referred to as digital transformation. This process of technology adaptation is particularly challenging for companies that were – in contrast to Amazon, Google, Microsoft, and others – not "born digital" since those companies need to undergo far-reaching business transitions that may well overturn established job designs and internal business processes and require novel ways of thinking and collaboration.

Many organizations in the public and private sector do, however, struggle to understand the implications of digital technologies for their business and service models. Most business leaders and employees mistakenly believe that digitizing documents and using Skype or Microsoft teams rather than the mobile phone will automatically result in the digital transformation of their organization. But digital transformation – as we will learn throughout this book – is much more than the integration of digital technologies into existing organizational structures. Digital transformation is about creating an agile, open-minded, constantly learning, and innovating business culture that unleashes the potential of digital technologies – such as quantum computing, blockchain technology, and artificial intelligence – to increase productivity and competitiveness and to create sustainable value for customers and employees. By digitizing their "core," that is, their most critical IT infrastructures, systems, and processes, organizations can remove traditional bottlenecks and enable unprecedented scalability and growth – digital is just an enabler and not a trendy end by itself.

According to a recent survey on digital transformation by McKinsey & Company, more than 80% of the companies analyzed say that they have undertaken such transformative efforts in the past five years already. But only a marginal fraction of 16% confirm that they succeeded in improving performance and making their business less susceptible to disruption and bankruptcy in the long term [1]. On the other hand, other business analysts have assessed the impact of digital transformation on jobs and employment and found out that almost 40% of current US jobs are in occupations that are likely to shrink [2] – similar figures can actually be found for other countries, too. On a global scale, this fraction translates into more than 75 million to 375 million workers that will need to switch their occupation and qualification skillset by 2030 in order to avoid unemployment [3] – a truly alarming scale. Those numbers impressively demonstrate that digital technologies will

reshape and disrupt organizations including thousands of jobs on the medium and long term. This is why it is essential for us as thought leaders, consultants, investors, or employees to get ready for digitalization and advance our skills, qualifications, and knowledge about digital technologies by studying their basic principles and learning about their applications. We do not need to become a quantum physicist, blockchain programmer, or data scientist alltogether. But having an overview on the digital technology stack and understanding its operating principles and capabilities will allow us to follow those trends in media, comprehend innovative products and services, evaluate applications and potential use cases, and finally drive the digital transformation in our own professional environment. Digitalization basically forms a mandate for all of us to actively shape the digital future ahead of us.

In this chapter, we will learn about the fundamental concepts of digitalization and digital transformation and better understand the nature and origin of their disruptive force. The presented concepts are the prerequisite for understanding quantum computing, blockchain technology, and artificial intelligence as the three most important technologies that enable and foster the digital transformation of organizations. But before we dive deep into those concepts, it is instructive to relate digital transformation to other historical transformations that have shaped our industry and society in the past.

1.1 Historical Business Transformations

Science and technology have always been shaping business and society. Historians who study this interdependence developed the idea that humankind went through four big *waves of technology adoption*, each of which was accompanied by severe changes in society and improvements of productivity in industry [4]. The first big wave is associated with the steam engine, which was invented by the English military engineer Capt. Thomas Savery in 1698 and converts the steam of boiling water to mechanical energy. Originally developed to draw water from flooded mines in the mining industry [5], the steam engine soon seeded technological innovations in other industrial sectors, too. Steam engines were used to power mechanized weaving looms in the British textile industry, for instance, where they boosted the productivity by eight times compared to simple spinning wheels. But the application of the steam engines was not only limited to the mining and textile industry. It also revolutionized the transportation industry with the arrival of steamships and steam-powered locomotives some 100 years later. Both innovations brought about further massive changes since humans and goods could move great distances in fewer hours from that time on. This period between 1760 and 1840[1] is referred to as *industrial revolution* or industry 1.0. The adoption of steam and water power

[1]Please note that those years are only a rough time indication. As with every new technology, transitions are continuous and cannot be specified accurately.

in the manufacturing and transportation industry had profound impacts on established companies and also fostered the exploitation of new businesses as human creativity was no longer limited to pure muscle power. But the industrial revolution did also have major impacts on society through creating new jobs and occupations, such as mechanical maintenance and quality engineers in the manufacturing space, and replacing manual labor by automated process. In consequence, this first wave of technology adoption increased the standard of living and made Europe as a whole less dependent on agriculture and more centered around the mass production of (consumer) goods – with all advantages and disadvantages.

In the 19th century, the pioneering work of the three physicists André-Marie Ampère, Michael Faraday, and James Clerk Maxwell became the foundational basis for the next wave of technology adoption, which refers to the discovery of electricity and is called *technological revolution* or industry 2.0. Electricity turned out to be a very convenient way to transmit vast amounts of energy, that is, the physical ability to perform work, across very large distances at minimum loss to power light bulbs, heavy industrial machines, and other electric devices. It also inspired the automobile pioneer Henry Ford to combine electricity with the idea of mass production and introduce moving chassis assembly lines to the automobile industry beginning with his Highland Park Ford Plant in 1913.[2] Traditionally, vehicles had been assembled in fixed work stations, with different workers coming to the vehicles to deliver and assemble the components required. On the assembly line, the vehicles would move through a series of sequential work stations on an automated conveyer belt with stationary workers that perform highly specialized, repetitive, and standardized assembly tasks. With the help of the American engineer Frederick Taylor and his principles for an efficient work process control known as *Taylorism*, Henry Ford managed to cut the assembly time of his legendary Model T – affectionately called the "Tin Lizzie" – by a factor of 10, an improvement that reduced manufacturing costs dramatically. With respect to standardization, Henry Ford once noted that "any customer can have a car painted any color that he wants so long as it is black." Electrically powered assembly lines soon boosted productivity in virtually all industries while reducing the manufacturing costs and physical strains of workers dramatically. It is needless to say that both electricity and the introduction of assembly lines between 1840 and 1970 had major impacts on society as they created numerous new jobs and occupations in the manufacturing space while rendering others obsolete.

Particularly relevant for the digital technologies introduced in this book is the third wave of technology adoption, the so-called *information revolution* or

[2]Henry Ford actually took the idea of mass production from a slaughterhouse in Chicago, where a series of pigs hung from conveyor belts at which each butcher only performed one specific part to butcher the animals.

industry 3.0. Beginning in the 1970s, companies began to automate industrial manufacturing by memory-programmable controls, the forefathers of personal computers. By employing such computer controls, they were able to partially automate their production processes without any human assistance. The technological basis for this technology dates back to 1947 and the discovery of the transistor by the three American physicists and later Nobel laureates John Bardeen, William Shockley, and Walter Brattain at the famous Bell Laboratories in New Jersey, America. This tiny little electric switch, which we will study in further detail in the following, soon became the basic building block of personal computers and virtually every electronic device that employs microchips to control manufacturing processes by processing digital information. IBM's first commercially available product based on transistor technology was the IBM 608 system, a cupboard-sized accounting calculator with more than 3,000 transistors in total. For comparison, the computers and electronic devices we use today are much more powerful and versatile in their application and can have several billion transistors in one microchip.

We are currently preparing for the fourth wave of technology adoption, the so-called *cyber revolution* or industry 4.0.[3] This period after 2017 generally refers to the application of information and communication technologies to industry. Industry 4.0 advances computer-controlled production systems by combining them with modern communication technologies to form a network of connected sensors and computing devices that allow for implementing something called *digital twin*. This virtual computer representation of a production line allows for the real-time optimization and statistical process control of production, allowing products to navigate through production lines autonomously while aiming to find the best production resources automatically. Such a network is also referred to as *Internet of Things* (IoT) and characterized by an interconnected system of electronic sensors and devices that is capable of automated sensing, data processing, analytics, and execution. The industrial Internet of things entirely changes the way people and machines interact with each other. Just think about intelligent collaborative robots that employ advanced sensing technologies to collaborate with workers safely to support them in performing complicated assembly tasks or handling heavy products. Further to this automation, the industrial Internet of things does also allow for implementing cost-effective predictive maintenance processes, self-optimizing production lines, automated inventory management, and other industrial processes that lend themselves well for an automated process control.[4] The Internet of things is also expected to foster the implementation of *smart factories* [8], in which the production system nearly operates autonomously and decision-making processes get automized by data analytics and other digital

[3]The term "industry 4.0" or "4th industrial revolution" was actually first coined on the World Economic Forum in 2016 [6].

[4]See BCG study entitled "Winning in IoT" for a detailed analysis of further use cases [7].

support technologies. An industrial IoT can either be implemented by leveraging computational resources on premise or by using external resources on demand, such as Siemens MindSphere, AWS IoT, and Google IoT.

INTERNET OF THINGS

The Internet of things is a network of connected objects that build an aware, autonomous, and actionable system. The data obtained from the different objects is aggregated on a storage platform to make it available for data analysis services and functions that combine different sources of raw data, analyze their jointly meaning, and translate it into concrete actions.

In this context, the renowned American economist and Harvard Business School professor Michael Porter – whose book about competitive strategy became a classic in the field[5] – already speculated back in 2014 that "it is the expanded capabilities of smart, connected products and the data they generate that are ushering in a new era of competition" [9]. Data is the new oil as *The Economist* described it [10], and the existential threat to established organizations that do not adapt those digital technologies is in fact very real [11].

1.2 Innovation and Disruption Theory

The attentive reader may have noticed in our previous discussion that the technologies that gave rise to the four waves of technology adoption, such as the steam engine, electricity, and the transistor, have three aspects in common. All of them

1. Are *pervasive* in their nature and not limited to a specific industrial sector. They rather branch out progressively to seed other technological innovations and trigger various spillover effects.
2. Offer significant *improvements* on the status quo in terms of technology, productivity, cost, and speed among others.
3. Are *complementary* to other (existing) technologies, such as steam engines that are for weaving looms or transistors for assembly lines.

This is why economists who study the linkage between scientific progress and technical change also call such technologies *general-purpose technologies* due to

[5]At a basic level, strategy generally refers to what a company wants to achieve and how it will get there.

their generic nature and versatile applications across multiple sectors [12]. General-purpose technologies are typically nonrival and long lasting and play the role of *enabling technologies* by opening up new opportunities and catalyzing new waves of complementary innovations rather than offering complete and final solutions [13] – a transistor on its own would in fact be fairly useless. The Internet is an excellent example for a general-purpose technology as it introduced new ways of producing, distributing, accessing, and reusing digital information that enabled innovations like online marketplaces and social networking platforms.

The adaptation of general-purpose technologies in established and *incumbent organizations* requires major organizational changes inside them as they typically focus on doing one specific thing in a very efficient way over time. For this purpose, they develop routines, built bureaucracies, career path, incentive systems, and embedded normative systems. Furthermore, they implement processes and establish legacy systems that reinforce each other and foster inertia, which make it increasingly difficult to adapt new technologies that often foster an organization to do things differently. This is why general-purpose technologies are a particular threat for established and very successful organizations, in particular. By referring to this widespread behavioral pattern, the two American economists Rebecca Henderson and Kim Clark also called such innovations *architectural innovations* to emphasize that their adaptation requires organizations to change the architecture between different internally used technological components and systems [14]. This can be very challenging for organizations but is often rewarding in the end. The concept of architectural inertia – the resistance to technology adaptation – also informed the *disruption theory* of Clayton Christensen and Joseph Bower at Harvard University in 1995 [15]. The two American economists were studying the hard-disk drive industry at that time and asking themselves why certain companies managed to gain and retain competitive advantage by adapting new technologies while others failed to do so and went bankrupt. In their concept, they differentiate two major categories:

1. *Sustaining technologies* improve or enhance the attributes of an existing technology or product that customers already value. They (i) make good products better, (ii) usually target the most profitable customers at the market's high end, and (iii) improve the profit margin. In other words, sustaining technologies enable better products that can be sold for higher profits to the best customers of a company. One example is flat-screen TVs that merely replaced TVs based on vacuum tube technology.
2. *Disruptive technologies* have entirely different or new attributes that deviate from what customers have valued before and are sometimes called the "children" of

general-purpose technologies in literature. They themselves fall into two subcategories, namely, low-end and new-market disruptions:

a. *Low-end* disruptions typically target overserved customers with affordable and accessible products that are just "good enough" but do not reveal superior performance beyond the market average.[6] Just think about discount department stores that figured out a cheaper way of doing the same thing like traditional department stores.

b. *New-market* disruptions compete against non-consumption and target customers, who did not have access to a product or service before. Compared to personal computers, smartphones can be understood in terms of new-market disruptions since they offer similar features than personal computers, such as Internet and email, while being affordable for (mass-market) customers who did not have access to personal computers due to the much higher costs of ownership. Steve Jobs, the legendary founder of Apple, described the first iPhone on its product release in 2007 with the famous words "Today, Apple is going to reinvent the phone [...]. It's the internet in your pocket for the first time ever." An important key characteristic of new-market disruptions is that they are widely adopted first before society adapts to them.

Later on, Clayton Christensen replaced the terms sustaining and disruptive technologies by sustaining and disruptive innovations when he realized that the disruption did not originate from the technology itself but rather from its impact on business strategies and models. In this context, it is important to note that almost never is an innovation intrinsically sustaining or disruptive. This attribute is rather given to it when deployed to a market and comparing it to other technologies that have been adopted by the market already. Flash drives, for instance – the technology behind USB-sticks – are disruptive for hard-disk drives but sustaining for DRAM technology[7] that has been used for building the working memory of personal computers.

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[6]Those are generally lower profit markets for incumbent players but attractive markets for new entrants. They are thus ideal for creating new growth opportunities as new entrants will usually try to move "upstream" to gain market share against incumbent players in more profitable market segments over time.

[7]DRAMs or "Dynamic Random Access Memories" encode digital information in electric charges. Unlike flash memories, DRAMs therefore lose their data quickly if the power is switched off. This is also why DRAMs are sometimes called "volatile memories," while flash memories are "nonvolatile."

Disruption is a force that has shaped markets and their competitive landscape ever since. As low-end and new-market disruptive innovations become mature and robust, they pose an immediate risk to incumbent organizations, who do not leverage emerging technologies to make their products and services better. The important point to note in this context is that disruption usually is an opportunity long before it is a threat for incumbent players in a market. One of the most famous examples highlighting this aspect is the legendary Eastman Kodak Company founded by the American businessman George Eastman in 1880. George Eastman formerly invented and patented a dry-plate formula for developing photographic film rolls, an industrial process that suited well for mass production. He then introduced an inexpensive (handheld) film camera in 1888 that was designed to use this technology. With the slogan "you press the button, we do the rest," he developed a very successful business model in the following years by focusing on cheap cameras and an efficient photographic film-developing process. Kodak soon became the market leader in this industry and commanded about 90% of film and 85% of camera sales in the United States [16]. But – as you might have guessed already – this photo empire fell with the disruption of digital cameras that entered the low-end market in the 1990s. Quite ironically, it was Steven Sasson, a Kodak engineer, who invented digital photography and built the worldwide first digital camera in 1975. But Kodak's management was very skeptic about this early prototype due to its low performance and did not see that its disruptive potential might redefine their business and eliminate competitive advantages that were accumulated over decades – disruptive technology is an opportunity long before it is a threat. Instead, Kodak's management opined that consumers will focus on printing again once the temporary trend of digital photography is phased out. This is why they started to protect their business by employing their huge marketing machine. In contrast to its major Japanese competitor Fujifilm, who integrated digital technology very well into its business, the disrupting force of digital photography contributed to Kodak's (architectural) inertia and did not catalyze any change or digital transformation. By the time they realized their thorough misjudgment and launched their first own digital camera, it was too late, and Kodak's downturn was inevitable. The 120-year-old company had to file for bankruptcy protection in 2012, sold off their patents, and reemerged as a much smaller company in 2013. In 2018, it reported around USD 1.33 billion of sales, one-tenth of the legendary value it reached 37 years before. This and numerous other examples prove that business disruption is a matter of when rather than if it will happen. This is why thought leaders should anticipate change by proactively looking and striving for self-disruption rather than coping with disruption when it happens.

The Kodak Eastman Company is just one example for what Clayton Christensen termed *innovator's dilemma* [17]. This term refers to the challenge of market-leading organizations to exploit existing core businesses while exploring new disruptive innovations that secure market leadership in future and avoid economic failure due to new disruptive players in the market. In case of Kodak, this dilemma manifested itself in deciding whether to invest in digital photography or not. Guided by marginal thinking, Kodak's management compared the marginal cost of their existing photographic film business with the marginal cost associated with digital photography and came to the misleading conclusion that it is much more profitable of pursuing their established film business. In other words, *marginal thinking* biased them to focus on what has been successful in the past, instead of guiding them to create the digital capabilities they will need in the future. Kodak ultimately failed to identify digital photography as a disruptive technology or the "next big thing" in this market and ended up paying the total cost[8] for not investing rather than the much lower marginal cost[9] for investing in digital photography. Economic failure is often the consequence of this marginal thinking. Compared to a mature core business, investments in future innovations including the three digital technologies introduced in this book almost always come with low marginal profits and high marginal cost. But since they often turn out to be crucial for an organization's success in future, it is important to evaluate investments in future innovations in terms of the total costs and strategic consequences associated with not investing in them – the marginal side of things is secondary. The American automobile pioneer and businessman Henry Ford described this insight nicely with the famous words "If you need a machine and don't buy it, you will ultimately find that you have paid for it and don't have it." With these insights, examples, and terminology at hand, we are now ready to discuss the three digital technologies introduced in this book in terms of general-purpose technologies that unfold a disruptive force and drive digital transformation.

1.3 The Digital Ecosystem

Due to their great relevance for business and society, digitalization and digital transformation are intensively studied in literature. Management consultancies as well as digital-age companies like Google, Microsoft, and Amazon frequently

[8] In economics, *total cost* is equal to the overall cost and the sum of fixed and variable costs being independent and dependent of the number of goods produced, respectively.

[9] *Marginal cost* is equal to the change in the total cost that arises when the quantity produced is increased by one unit. Classical finance and economics suggests to evaluate alternative investments in terms of marginal costs and revenues, which is not suitable for evaluating strategic future investments.

publish insightful articles and reports about them on their blogs.[10] Different definitions for digitalization and digital transformation evolved over time, each of which highlights different aspects. The two communication scientists Scott Brennen and Daniel Kreiss, for example, define digitalization through the impact of digital communication and media on contemporary social life [18]. A more practical definition is provided by the Oxford English Dictionary, which traces the first uses of the term "digitalization" back to the arrival of computers in the mid-1950s and defines it as "the adoption or increase in use of digital or computer technology by an organization, industry, country, etc." Furthermore, this principle dictionary of the English language differentiates between digitalization and digitization with the latter being defined as "the action or process of digitizing; the conversion of analog data (esp. in later use images, video, and text) into digital form." One of the most intuitive definitions can actually be found in Gartner's IT glossary, which provides the following definitions for those terms[11] [19]:

- "*Digitization* is the process of changing from analog to digital form [...]. Said another way, digitization takes an analog process and changes it to a digital form without any different-in-kind changes to the process itself."
- "*Digitalization* is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business."
- "*Digital transformation* can refer to anything from IT modernization (for example, cloud computing), to digital optimization, to the invention of new digital business models. The term is widely used in public-sector organizations to refer to modest initiatives such as putting services online or legacy modernization."

In other words, digitalization and digital transformation are entrepreneurial change processes that are enabled by digital general-purpose technologies. The definitions suggest that the three terms are inherently linked to each other and appear consecutively. This is why scholars sometimes visualize the relationship between them by using a pyramid structure depicted in Figure 1-1 exemplarily. This simple graphics illustrates that digitization, digitalization, and digital transformation are built on each other with digitization being the foundational basis of them. Digitization simply converts information from sensors and other inputs to a digital format that allows for further data processing. Digitalization on the intermediate level uses this digital information to draw conclusions or find insightful hidden patterns that allow for saving

[10] See, for example, www.blog.google/, https://blogs.microsoft.com/, and https://aws.amazon.com/de/blogs/.

[11] Further definitions of those terms can be found in [20, 21], for example.

money by optimizing and automating business processes. The highest level of this pyramid is digital transformation. It allows companies to save money but also earn additional money by creating new markets and providing new business opportunities. Digital transformation is enabled by digital technologies. This is why it is sometimes referred to as *technology-driven digital transformation* to emphasize that it relies on the integration and interdisciplinary convolution of different digital technologies into all core areas of an organization – an important aspect, which we will discuss in more detail in the following.

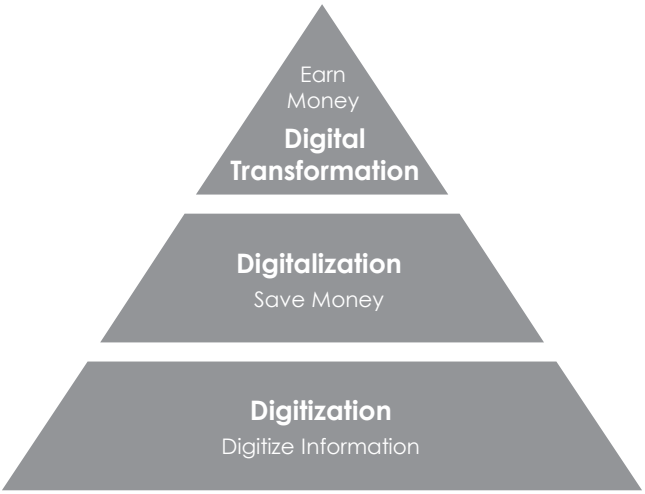

Figure 1-1. Relationship between digitization, digitalization, and digital transformation

DIGITAL TRANSFORMATION

Digital transformation is a journey of strategically planned and far-reaching change process to implement a software- and data-centric organization. It is enabled by digitization and digitalization and fostered by leveraging digital support technologies, such as quantum computing, blockchain technology, and artificial intelligence.

Digital technology generally facilitates the (1) processing, (2) communication, and (3) storage of digital information. The timely evolution of each of those core aspects has been described in terms of three exponential laws that have been observed empirically in the last few decades:

1. *Moore's law* describes the exponential evolution of processing power and states that the number of processing units in computer chips doubles every 18 months [22].

2. *Butter's law* relates to the communication speed of networks, which doubles every 9 months [23].
3. *Kryder's law* states that the storage capacity doubles every 13 months [24].

Those are truly exponential and breathtaking timescales given that established products, such as automobiles, take more than 24 months of development time. While the three core dimensions of digital technologies reveal an exponential timely evolution, our brain is generally not used to such exponential developments. This is also why most leaders underestimate the impact of digital technologies on organizations, as they often revealed linear developments over the last couple of years. The resulting gap between the exponential technology and linear business evolution is depicted in Figure 1-2 for clarity. It can generally be associated with unexploited business opportunities and is frequently filled by innovative startup companies that exploit digital technologies. This performance gap increases over time and visually captures the need for technology-enabled digital transformation.

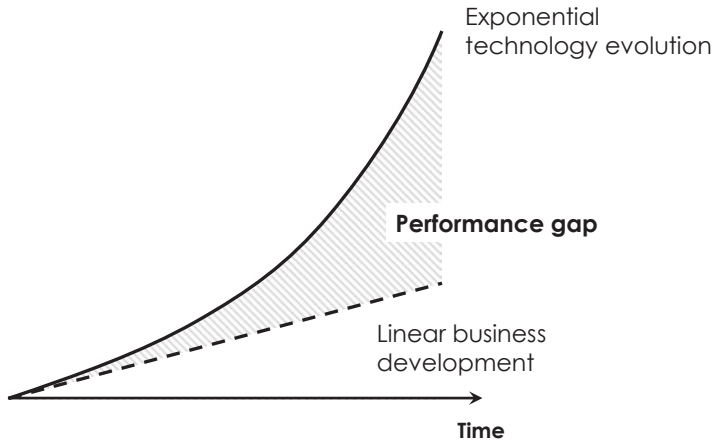

Figure 1-2. Linear business development (dashed line) vs. exponential technology evolution (solid line). The resulting gap (hatched area) is often filled by innovative startups

But digital transformation is much more than the integration of digital technologies into an existing IT infrastructure for making processes paperless as mentioned earlier. The CIO community "The Enterprisers Project," for instance, notes that "Digital transformation is the integration of digital technology into all areas of a business, fundamentally changing how you operate and deliver value to customers. It's also a cultural change that requires organizations to continually challenge the status quo, experiment, and get comfortable with failure" [25]. Digital transformation helps organizations to

continue the progress of productivity and competitiveness in an increasingly globalized and connected world that is characterized by severe economic, environmental, and societal changes. The example of Kodak does – among others – clearly reveal that organizations who resist certain technologies are at risk of disruption.

Experts have suggested various factors that could signal an industry's vulnerability to disruption. The most important signs for disruption are

- Customer satisfaction is decreasing.
- Customer base is aging.
- Customers are inconvenienced [26].
- Customer loyalty is low [27].
- High costs of products and services trigger the use of technology to save costs rather than add value to the customer's life [26].
- Increased interest from venture capitalists, who – as outsiders – see hidden opportunities in the sector.

If we compare those signs with the state of current industries, such as the automotive or healthcare industry, you may quickly notice that virtually all companies face similar challenges and threats to their business today like Kodak did about 28 years ago [28]. Companies are nowadays exposed to an increasingly complex world characterized by the diffusion of digital technologies into their *ecosystem.*[12] But complexity is not the only force that drives the digital transformation of private and public organizations today as we will see in the next section.

1.3.1 Major Driving Forces

Digital disruption is a very strong force that has been changing the corporate landscape ever since. Today's organizations are not just being driven to integrate digital technologies into their core processes. They do also frequently find themselves competing with innovative new players outside of their own industry now, such as automobile manufacturers and mobility service providers [28]. As vehicles are becoming increasingly connected, the business model of established automobile manufacturers is threatened by digital business models that deliver marketplaces for on-demand entertainment and infotainment services. Both features are increasingly embedded in the vehicle's ecosystem and target drivers and passengers of autonomous vehicles in transit, for

[12]Ecosystem refers to a business network of organizations and individuals that exchange goods, services, and information to create a certain value for customers and other players in the market.