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Volume 1

Technological Change

Clotilde Coron

Patrick Gilbert

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Technological Changes and Human Resources Set

coordinated by
Patrick Gilbert

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Contents

Introduction ix

Chapter 1. The Human and Social Sciences in the Face of Technological Change 1

1.1. Approaches to technological change 1
1.1.1. Technological determinism 2
1.1.2. Social constructivism 14
1.1.3. Joint structuring of technical and social aspects 19
1.1.4. Limitation of established distinctions 27
1.2. A brief history of technological change 27
1.2.1. How can we tell the story? 28
1.2.2. At the origins of the Industrial Revolution (from the Middle Ages to the Renaissance) 30
1.2.3. The First Industrial Revolution (end of the 18th Century) 32
1.2.4. The Second Industrial Revolution (late 19th Century to the 1910s) 34
1.2.5. The Computer Revolution (from the late 1960s to the 1990s) 36
1.2.6. The Digital Revolution (early 21st Century) 38

Chapter 2. Technological Change and Society 43

2.1. Powers, institutions and technological change 44
2.1.1. Fundamentals of political analysis and technology 44
2.1.2. The role of the State 45
2.1.3. Technological change in the age of globalization 50
2.1.4. The dark side of technology. 52

2.2. Ethics in the face of technology 57
2.2.1. Ethical evaluation of technology 57
2.2.2. Three ethical issues under discussion 60
2.3. Technological change and diversity 66
2.3.1. Inclusive technology/exclusive technology. 67
2.3.2. Technologies that reflect their designers 75
2.4. Technological change and ecology 78
2.4.1. Technology, an answer to ecological challenges? 78
2.4.2. Technology as a source of ecological degradation? 82

Chapter 3. Technological Change and Organization 87

3.1. Omnipresence of the technical object in work activities 87
3.1.1. The R&D function in the lead 88
3.1.2. Marketing challenged by digital transformation 89
3.1.3. Factory 4.0 90
3.1.4. e-HR 93
3.2. The interaction of technological and organizational systems. 95
3.2.1. Technological change and organizational structure 95
3.2.2. Technological change, and financial and human resources for innovation 100
3.3. Technology as a liberator and control agent. 104
3.3.1. Prescriptive and assistive technologies 104
3.3.2. Technological ambivalence: the same technology for empowerment and control purposes 111
3.4. Technological change as a social process 113
3.4.1. Changes in the social entity and management methods 114
3.4.2. Support for employees whose activities are threatened by technological change. 121
3.4.3. The actors of technological change in organizations 127

Chapter 4. Technological Change and the Individual 135

4.1. Activity and technical object. 136
4.1.1. The technical object in the activity system 136
4.1.2. The technical object and its mediations 138
4.2. The encounter between the individual and the technical object 142
4.2.1. The individual in the design phase. 142
4.2.2. The individual in the adoption phase 144
4.2.3. The individual in the use phase. 148
4.2.4. The individual between subject and object 151

4.3. Beyond the content of activities, a transformation of working structures 154
4.3.1. Variable effects depending on the technological equipment 154
4.3.2. The emergence of new work characteristics 155
4.3.3. The growth of telework 156
4.4. Technological changes and individual skills 158
4.4.1. Skills and their production 158
4.4.2. Digital skills as frames of reference 161
4.4.3. No digital skills outside the activity 163

Chapter 5. Experiencing Technological Change 165

5.1. Threats and opportunities associated with technological change in organizations 166
5.1.1. Overview of threats and opportunities associated with technological change 166
5.1.2. Threats and opportunities also concerning work organizations 168
5.2. Reconciling technical and social issues 171
5.2.1. Social or responsible innovations: definitions and examples 172
5.2.2. Responsible technological innovations within organizations 179
5.3. Managing responsible technological change 183
5.3.1. Organizational change management 183
5.3.2. The specificities of technological change 189
5.3.3. An integrative scheme for the management of responsible technological change 200

References 203

Index 219

Introduction

For a long time, technological change was considered synonymous with economic and social progress. Today, it stimulates some and worries others. To take just one example, the most emblematic, the massive arrival of new digital tools is disrupting consumption patterns, forms of employment and working conditions, and posing many challenges for organizations and individuals alike. While it is recognized that technological change is a key determinant of economic growth, it is also true that it can also amplify or even catalyze inequalities (by age, gender, level of education and skills, income, etc.). In short, technological change is also a social change with which it maintains complex interactions: technology is as much the source, ambivalent, as the consequence of social transformations. In particular, individuals are both human resources of technological transformations and receivers, more or less capable and accepting of its effects.

I.1. First definitions

The phenomenon we are about to discuss has a long history. However, there is still some uncertainty about the meaning of the terms used to describe it, so it is useful to start with a few definitions.

I.1.1. *Technical, technological and technical objects*

There is some confusion between the technical and technological, probably because of the respective connotations of these terms in everyday language.

Today, the term “technological” tends to be used as a superlative of “technical” for which it is sometimes substituted. More pretentiously, it has come to refer to a modern and complex technique, such as information and communication processing techniques. While the term “technical” refers to well-demarcated know-how and the traditional industrial universe, the term “technological” is spontaneously associated with modern values. Resisting the current tendency to make the terms somewhat synonyms, we will follow the tradition introduced by sociologist and anthropologist Marcel Mauss (1872–1950), and extended in the anthropology of techniques, notably by Leroi-Gourhan (1911–1986), André-Georges Haudricourt (1911–1996), and others, by designating the technical the “effective traditional act”.

Let us take up the three elements of Mauss’ formula: the act, tradition and efficiency. First of all, a technology is not defined by a collection of objects, but by the concrete action it exerts on the world. It must be effective because, without sensitive effects and known as such, an act cannot be designated as such. Moreover, this act is described as traditional. For if it is not linked to a tradition, an act is neither intelligible nor reproducible, and cannot be transmitted to others.

Technologies are also based on invention and innovation, but they are not themselves totally independent of the knowledge and know-how accumulated in a given culture. Specifically, technology refers to all the processes and methods used in the production activities of an object or service. It is a real need for scientists, engineers and industrialists. But, undoubtedly precisely because of the diversity of these needs, it can hardly lead to a representation that is unanimously accepted.

As for technology, it is, according to the classical definition, the social science that takes a technique as its object, the study of techniques, tools, machines and materials. However, it should be recognized that clearly distinguishing the two concepts may seem difficult. Therefore, we will admit, by extension and according to a widespread use, the use of the term technology as a grouping of the techniques, procedures, methodologies, equipment and discourses associated with their implementation. In this second sense, we will speak of digital technology, biotechnology, agro-technology, etc.

In any case, we will not confuse the technical object, the product of human activity, with technology. The technical object is only one of its elements, the most concrete, the hard material of technology, "hardware". It is a solid thing consisting of one or more tangible and intangible components (organs, information, energy and other resources), functionally arranged, designed and realized to meet a specific need or needs. Among the technical objects, we will distinguish between the technical equipment (infrastructure, machinery and tools) used to produce other objects, and the resulting products (see Figure I.1).

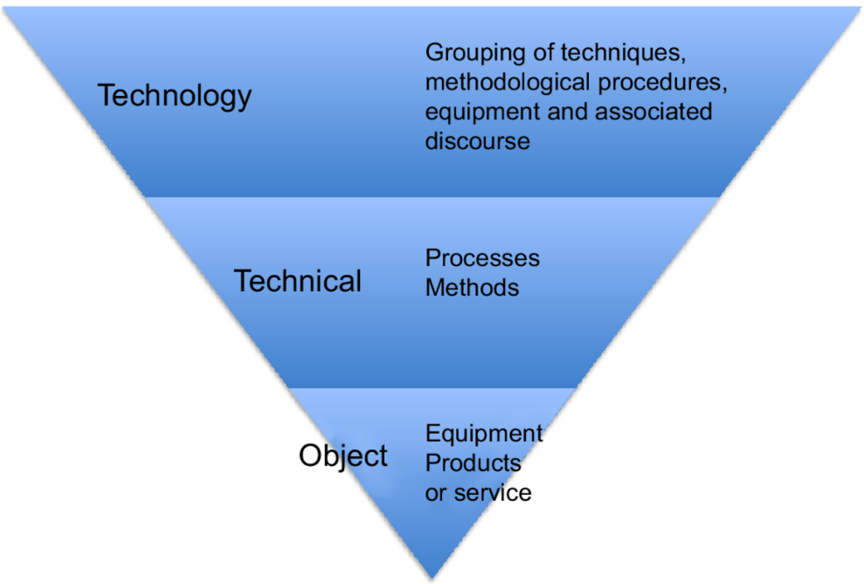

Figure I.1. *From technology to object*

These clarifications are proposed as conventions that we would like to share with the readers of this book. They will lead us, for example, to consider digital technology as the grouping of a set of technologies covering fields of application as diverse as medicine (video-endoscopy), prototype production (additive manufacturing or 3D printing), architecture (Building Information Models, or geometric representations of a building in 3D), and graphic creation (digital comic strips). Each of these technologies in turn brings together several objects. Thus, additive manufacturing is based on printers, producing objects as varied as functional parts, tooling components, models for metal casting, etc.

Talking about technological change and not technical change is not insignificant. The term "technological change" emphasizes the need not to separate methodical processes from the principles that reflect them and from the ecosystem (economic, social, organizational, ideological) in which the technologies lead to successful practices. In this sense, technological change is not reduced to a change of processes (i.e. a technical change) and even less to a simple change of technical object. Thus, digital transformation is not just about the arrival of a few objects offered to consumers. It leads to a transformation of work structures as a new division of labor between the operator and the machine[1].

I.1.2. *How can we address technological change? First elements*

Technological change can be approached from three main perspectives. The techno-centric perspective (centered on the technical object) is usually contrasted with the anthropotechnical perspective (centered on the human-technical couple). Between the two, we will insert a "romantic" perspective, based on the joint glorification of the inventor and the object of his creation. We will define these three points of view by illustrating them and considering them both at a "macro" scale (that of the history of technologies) and at a "micro" scale (that of organizational change).

I.1.2.1. *Technocentrism: the primacy of the technical object*

The dominant representation of technological change, conceived in terms of the technology itself, corresponds to a perspective that has been described as techno-centric (Jacob and Ducharme 1995; Rabardel 1995). It is focused on the machine and its possibilities. This is the case for a history of computing in terms of generations of technical objects (see Box I.1).

1 Throughout the book we favor the use of the terms "technology" and "technological" to facilitate reading. In French, the authors' native language, two terms can be used: "technique" and "technologique" and "techniques" and "technologies".

1945–1955	First generation: electronic tube machines (vacuum tubes). The first fully electronic computer, the ENIAC (Electronical Numerical Integrator And Calculator) weighs 30 tons and occupies 135 m^2.
1955–1965	Second generation: transistor computers that make it possible to build more reliable and less bulky machines.
1965–1980	Third generation: integrated circuits (also called electronic chips). The Intel 4004 processor achieves the same performance as the ENIAC for a size of less than 11 mm^2.
1980–2000	Fourth generation: microprocessors. Integration of thousands to billions of transistors on the same silicon chip.
2000	Fifth generation: widespread use of networks and graphical interfaces (there are disagreements between specialists about the existence of this fifth generation).

Box I.1. *Computer generations from a techno-centric perspective*

This first perspective, concerned with the object and its materiality, does not address the human dimension of technological change. At the organizational level, it can lead to neglecting the individual who becomes the residual part of technological change, the part that is said to resist change.

I.1.2.2. *The romantic perspective: the inventor and his creation*

Here, technological change is often represented as a chronological succession of technical objects with which glorious personalities and events are associated, such as the one we have taken up, by way of illustration, in Box I.2.

This tenacious tendency undoubtedly gives an attractive representation of technological change because of its simplicity, its exaltation of the idea of progress and the myth of great men. But it will not be our preference. To attribute to a single individual, at a given date, an invention when it is usually the result of a maturation, resulting from parallel research, seems to us to be from a romantic perspective.

1769	James Watt develops an improved condenser for the steam engine.
1821	Michael Faraday demonstrates the first electric motor.
1838	Charles Wheatstone builds the first electric telegraph.
1859	Étienne Lenoir makes the first internal combustion engine.
1876	Alexander Graham Bell files a patent on the telephone.
1879	Thomas Edison develops the carbon filament bulb.
1884	Hiram Maxim invents the first self-propelled machine gun.
1899	Guglielmo Marconi makes the first transatlantic radio transmission (which won him the Nobel Prize in 1909).
1903	Brothers Orville and Wilbur Wright make their first motorized flights.
1923	Vladimir Zworykin patent the iconoscope, a fully electronic television transmission tube.
1947	Bardeen, Brattain and Shockley (Nobel Prize winners in physics in 1956) invent a new type of transistor.
1957	The Soviets launch Sputnik 1, the first spacecraft placed in orbit around the Earth.
1969	Edward Hoff and Federico Faggin develop the very first electronic chip, the microprocessor.
1973	François Gernelle develops the first microcomputer, the Micral N.
1977	Designed by Steve Wozniak, the Apple II, a personal computer, is developed in Steve Jobs' garage, manufactured on a large scale and marketed by Apple Computer.
1982	Microsoft, created by Bill Gates and Paul Allen, presents MS/DOS (Microsoft Disk Operating System) developed for the IBM PC, then for compatible PCs.
1994	Jeff Bezos founds the Amazon website, which becomes the world's largest online sales company. He lists the shares on the stock exchange in 1997.
1998	Google is created by Larry Page and Sergey Brin, two students from Stanford University, who together initiate the search engine of the same name.
2005	Mark Zuckerberg founds the online social network Facebook, after testing it on his fellow students at Harvard University.

Box I.2. *Technological change as a succession of uses*

This second perspective leaves little more room for the human being than the first, at most the latter is thought of as the progenitor of the technical object. The emphasis on the glorious origins of a tool is reflected at the organizational level when technological change is referred to exclusively in reference to the individual who was at the origin of a technological innovation and who gives it a prestigious character.

I.1.2.3. *The anthropotechnical perspective: towards a sociotechnical coupling*

The opposite of technocentrism is anthropocentrism, a vision of technologies centered on individuals and social groups. The technologies are thought of in reference to the human being and not the other way around. However, we will avoid any radicalism.

In practice, we do not intend to focus solely on individuals and their needs, but rather to consider how to achieve co-adaptation between object and subject. This is what we call an anthropotechnical approach. We will present different theoretical currents in Chapter 1 in more detail.

The focus on the uses of technologies, and no longer on the objects themselves, as they couple the human and technological, is a good illustration of this approach (see Box I.3).

1955–1960: from scientific computing to management computing

At the beginning, computing was mainly concerned with scientific calculation and operational research. It was then the business of engineers, the only ones capable of programming the automaton in machine language that they used for their own needs. Then management applications were born, still transposed from mechanography.

1960–1970: development of management applications

Scientific applications began to develop with the progress of numerical analysis and simulation (science, engineering, economics, etc.). At the same time, applications began to multiply in banking, insurance and finance. Cobol, a modern programming language dedicated to business applications, was created in 1959. The birth of the concept of an information system gave a global view of the company: processes and information flows.

1975–1990: computing for all

With the development of computers in terms of power and reliability, computers took over all social practices of research, design, manufacturing, marketing and communication. Microcomputing has enabled the wide diffusion of microprocessor-based computer components in technical systems and the creation of microcomputers. Networks allow computers to communicate and allow machines to be decentralized as close as possible to workstations.

1990: integration into business

Computing began to penetrate all sectors of the company: the business world became digital. In the mid-1990s, with the Internet and electronic mail, inter-individual and inter-organizational exchanges were organized via IT support. Information technology was no longer separable from other fields of human activity. Information and communication technologies began to be adopted by the majority of the population in their daily lives.

Box I.3. *A history of enterprise computing centered on usage*

Without departing from the anthropotechnical posture, we will avoid as much as possible a partisan posture, striving to reflect the diversity of points of view.

I.2 Technology, a social science

I.2.1. *Three pillars*

If, as we have written, technology is the social science that takes techniques as its object, on which pillars should such knowledge be based? We can see three of them in particular.

I.2.1.1. *First pillar: the acceptance of plural points of view*

The first pillar is the acceptance of plural points of view in the way the technical object and technological change as a whole are viewed.

The same technical object can be approached from different points of view, each with its own value, which is not intrinsic, but depends on the identities and cultures of the actors who mobilize them. In the study of the object, each point of view, whether disciplinary, doctrinal or utilitarian, reveals facts and mobilizes specific methods. Let us take the example of a smartphone. It can be studied from a purely physical point of view; we are interested in its weight, the definition and size of its screen, the shock resistance of its shell, its processor and its storage capacities. From the point of view of its manufacture, it is considered as a product consisting of thousands of small components (resistors, transistors) placed between the main chips of the device that must be soldered automatically, all in a production system in which machines and operators must be integrated. From an economic point of view, as a commodity, we are concerned in particular with its price with or without an associated subscription, its value in a summation system. From the point of view of its uses, we will focus on its functions (work, play, checking emails, watching videos, using social networks), their diversity and performance, battery life, and the quality of after-sales service. From an artistic point of view, we will be curious about its more or less attractive design (plastic material, glass or metal, color), the appeal of its brand and model, etc.

These plural points of view are obviously also reflected in the course of technological change and in the perception of the various actors: the designer of the technical object, the promoter of change, the pilot of the project or a simple user. In its simplified form, the consideration of this reality finds its expression in the duality of project manager/developer. When a product is being created, the project manager is the person or company (design office, architect, etc.) responsible for the design. They ensure the follow-up of the work and the co-ordination of the various tasks. The contracting authority is quite simply the user, the customer and the person for whom the product is intended.

I.2.1.2. *Second pillar: the contextualization of the technical object*

The second pillar is based on the contextualization of the technical object, i.e. the renunciation of the simplicity of isolating the envisaged object from situations in which it plays a specific role and from the time in which it evolves. For each object's ecosystem there is a coherent set of structures dependent on each other; this is what Bertrand Gilles (1978) called a technical system. The technical object only exists because someone has designed it; others have produced it, because there are individuals who feel the need or desire to seize it. To achieve this, it is necessary to extract raw materials, process them, transport the products at different stages of production, market the manufactured object, distribute it, allow its use (private or public) – and, increasingly pertinent given its ecological dimension, its destruction and/or recycling. All this requires multiple resources: materials, energy, money and human resources to mobilize other resources.

I.2.1.3. *Third pillar: taking into account the interaction between the human system and the technical system*

The third pillar of this anthropotechnical approach is to take into account the interaction of the human and technical systems. In this context, let us take the history of computer science as an illustration. It has several dimensions, technical, of course, but also economic and social. In this regard, it should be noted that the computer, like the Internet, was born of a convergence of scientific and military interests. Or, as Breton (1987) explained, the orientation of industrial groups towards large systems was in line with the centralized functioning of these groups. Breton showed that the birth and diffusion of the microcomputer in the 1980s owed as much to the social project of North American radicals, calling for the democratization of access to information, and to the willingness of the individual user to appropriate this technology, as to microprocessor technology.

I.2.2. *Contributions of the human and social sciences (HSS)*

The HSS cover a range of disciplines studying human reality, both individually and collectively. Technologies are one of the elements of this reality. Understanding technological change is based on this diversity, whose contributions are complementary. We will review the disciplines with the most important contributions by citing some of their classic authors and publications. We will come back to some of them in more detail later in the book.

I.2.2.1. *History*

History focuses on the study of technical achievements in relation to their context of appearance. More broadly, it is interested in all historical forms of conception and insertion of technologies in human societies. It is a resource for the development of reflections on the technique of other disciplines, particularly philosophy, anthropology and sociology. Among the most eminent personalities in the history of technology are Lewis Mumford, critical author of *The Myth of the Machine* (1966), and Bertrand Gille (1978) who, affirming that a technology does not exist if it is not included in a system, proposed to see history as a succession of technical systems.

I.2.2.2. *Philosophy*

The philosophy of technology is the part of philosophy that is concerned with the meaning of technologies, i.e. their nature and value for humanity. Let us begin by mentioning Karl Marx and Friedrich Engels who, in their *Communist Manifesto* (1999 (1848)), considered the determination of politics on a techno-economic basis: the hand mill corresponded to slavery; the water mill to feudal society; the steam mill to an industrial capitalist society. Considered as a whole, the philosophy of technology is shaped by two traditions. The first focused on alienation, in which technology would be the vector and symbol. The most emblematic author of this trend is certainly Martin Heidegger (1958), who is known for his denunciation of the extension of technical domination. In a similar way, Jürgen Habermas (1973) criticized techno-scientific ideology. In contrast to this pessimistic situation, we can contrast a second, optimistic orientation led by authors such as Gilbert Simondon (1969) and François Dagognet (1989, 1996), or a third orientation, inspired by the precautionary principle, such as the one led by Hans Jonas' ethics (1903–1993).

I.2.2.3. *Anthropology*

The anthropology of technology is a branch of anthropology that is interested in the history, use and roles of technical objects in their relationship with cultures and environments. Originally focused on technologies and objects from distant, "primitive" and exotic cultures considered as "traditional", its analyses also now focus on contemporary facts. Marcel Mauss (1923), considered the father of French anthropology, André Leroi-Gourhan (1943, 1945), author of a general classification of technologies, and André-Georges Haudricourt (1955), who was also a botanist, linguist and geographer, all already mentioned, are among the founders of the anthropology of technology.

I.2.2.4. *Sociology*

Sociology studies social facts in their entirety (general sociology) and within companies and other organizations (sociology of organizations). Sociologists have contributed to the understanding of technological change by studying individual and collective behaviors in organizations.

Some sociologists have focused on humans' relations with the machine, for example, Georges Friedmann (1946) or Georges Gurvitch (1968), others such as Jacques Ellul (1954, 1988), in a very targeted way, on the relations between the technical system and political power. Sociology has also made important contributions to the change in which technology is engaged. We are thinking, in particular, of Alain Touraine's first studies (1955) on the evolution of workers' activities in Renault factories, showing the reorganization of skills and power relations linked to the introduction of new technologies; or, further yet in other empirical fields, to the work of innovation sociologists such as Madeleine Akrich, Michel Callon and Bruno Latour (2006).

I.2.2.5. *Economic sciences*

Economics studies the functioning of the economy. It deals, from a resource allocation perspective, with all the activities of a human community relating to the production, distribution, trade and consumption of products and services. Among thinkers who have devoted part of their work to technological change and its effects, we can cite the name of Joseph Schumpeter, who developed a theory of creative destruction and innovation (1999 (1926)); Jean Fourastié, who is known for his technological optimism (1949); and Alfred Sauvy, author of the spilling theory, who noted the positive effects of technological progress on productivity and ultimately on employment (1980).

I.2.2.6. *Psychology*

Psychology seeks to explain human behavior. Since its inception at the end of the 19th Century, it has concentrated on working conditions and human–machine relations with a view to co-adaptation. But its direct contributions to the study of technological change are less long-standing. In recent years, it has contributed to enriching knowledge on phenomena such as the acceptability of technologies, the learning of their uses, and the place of technical objects in activity systems. Ergonomic psychology has focused its efforts on psychology's contributions to the design of work systems, which are increasingly influenced by technology. A branch of social psychology, organizational psychology deals with the influence in organizations of structural factors on psychosocial relationships between individuals, such as the influence of technology on the structuring of working time and the sharing of tasks.

I.2.2.7. *Multidisciplinary authors and interdisciplinary human and social sciences*

Classifying authors by discipline is not always easy (Table I.1), as a common feature of many of those who have been interested in technology is that they are curious minds, whose contributions are not limited to a disciplinary field. Let us take a few examples, among the well-known personalities, without claiming to be exhaustive. First, we will see philosophers. Simondon was also a psychologist – he taught psychology for a dozen years – and Dagognet did work in the history of science. And now, we will see sociologists. Friedmann, a philosopher by training, is best known as a sociologist of work who has always sought to maintain the link between sociology and humanist philosophy, just as Gurvitch has nourished his work with a philosophy of society. Finally, where should Karl Marx, whose work covered economics, philosophy and sociology, be included?

Discipline	Consideration	Subject of study
History	Technologies and their development	Genealogy of the appearance and dissemination of technical achievements
Philosophy	The meaning of technologies for humanity	Nature of the technology Value of technology for humanity
Anthropology	The uses and roles of technical objects	Material culture Technical innovation and societal transformations
Sociology	Social groups, technology and their interactions	Technical power, technical democracy Perceptions and social influences of technology Mediation and communication methods
Economic sciences	Production, trade and consumption of goods and services	Relationship between technology and economics Effects of technological progress on employment
Psychology	Individual and collective conduct at work in a technical environment	Attitudes, learning, satisfaction, adaptation, acceptance of new technical objects Productive activity and technical mediations

Table I.1. *Contributions of the humanities and social sciences*

Apart from the disciplinary contributions mentioned above, there are object-oriented sciences that involve several source disciplines, such as information and communication sciences, the purpose of which is the study of communication and for which communication is rather an object of interdisciplinary knowledge. The management sciences, which aim at the instrumental regulation of organized collective activities, have made some contributions, albeit still limited, to the question of technology. It is precisely to the task of reducing this gap that this book would like to contribute.

I.3. Structure of the book

The chapters that make up this book are based, each in their own way, on the foundation of the anthropogenic perspective. They can be read, in a classic way, according to the succession of their numbering, but also in different orders. However, we first invite you to read Chapter 1, which provides the essentials to understanding the whole, focusing on the contributions of the human and social sciences (HSS) to understanding technological change.

The following three chapters are independent of each other and can be read according to the reader's interests. They are built on the principle that in order to understand technological change and regulate its effects, it must be addressed at its different scales: that of society as a whole (Chapter 2), that of the organization, public or private, market or non-market (Chapter 3) and that of the individual, expert or layperson (Chapter 4). Although focusing on the level of the organization, the project of the book is to clarify the subject at different levels, by convening the disciplines of the HSS applied to it.

The fifth and final chapter looks at how technological change is experienced, depending on where you are. It functions to summarize and discuss the various elements presented in the previous chapters.

At the end of the book, the reader will find an extensive bibliography that will allow for in-depth study of one or more of the topics covered, as well as an index that will organize thematic entries for the text.

1

The Human and Social Sciences in the Face of Technological Change

Discourses on technological change are numerous and do not owe everything to social scientists. Engineers as well as merchants, philanthropists as well as intellectuals, have a point of view on the subject. Crossed by multiple conceptions, these discourses sometimes intersect and merge.

In order to disentangle this and to reflect the diversity of approaches, this chapter focuses firstly (section 1.1) on their summative presentation, concluding with the presentation of the anthropotechnical perspective, which shows the interdependence between technical and social factors. Inspired by this perspective, the second section examines the long history of technological change and its most recent developments (section 1.2).

1.1. Approaches to technological change

We will approach our subject according to the postulated relationship between technology and society. Technical historians have wondered whether inventions are inevitable, whether the machine makes history. But economists, on the other hand, have wondered whether it was not rather social demand that led to innovation. Sociologists have also questioned the relationship between technical innovation and social transformations. Philosophers have often been critical, but sometimes also adopted the cause of technophiles.

Technological Change, First Edition. Clotilde Coron and Patrick Gilbert.

Following Vinck (1995), it should be noted that technology and society have generally been thought of as two distinct spheres, one of which influences the other. In relation to this conception, in a first approach, technology is seen as exerting its influence on the social sphere, which is what is referred to as technological determinism (section 1.1.1). The opposite approach assumes that the influence of society is exerted on the technology, what Vinck calls "social constructivism" (section 1.1.2). A third approach, with which we will agree, postulates the mutual influence of technical and social aspects, or even the fusion of technical and social ingredients (section 1.1.3).

We ask that the reader forgives the deliberately extreme presentation of these approaches, given that few authors claim to be clear-cut about all the hypotheses that we will highlight and that characterize each approach.

1.1.1. *Technological determinism*

Technological determinism takes many forms, which will justify the place we will give it, first for a general presentation and then for that of its two antagonistic orientations. This is how the debate on technology is too often concluded: a dispute between those who link the fate of the social matter to the development of technology (technophiles) and those who, on the contrary, oppose them (technophobes). Beyond these oppositions, both sides come together in the idea that technology determines social matter.

1.1.1.1. *Technology as an element in determining social behavior*

The founding assumptions of this approach, considered in its most absolute form, are as follows:

– daughter of science, technology is an autonomous variable;

– a society is determined by the technologies in use;

– the technical evolution is linear, due to the irreversibility of the technologies;

– for better or for worse, the technological imperative is imposed on everyone: it is inevitable and universal.