# 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.

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.

For example, Canadian historian Harold Innis (1894–1952), a pioneer in the formulation of communication theories (Innis, 1950), associates the spread of the papyrus with the development of the Roman Empire and bureaucratic power. He then states that the invention of the parchment led to a shift from places of knowledge to monasteries and a strengthening of religious power. The latter is, in turn, reduced by the invention of paper, which encouraged the development of trade in Italy and northern Europe.

Another classic author case, among the most characteristic of this trend, is that of the American sociologist William Ogburn (1886–1959) who explained that technology changes society by changing the environment to which individuals, in turn, must adapt. This change, he believed, is common in the material environment, and the adaptation we make to it often changes social mores and institutions. He deduced that inventions influence society, first by being produced in large quantities and then by being used by a large number of consumers. Ogburn devoted several studies to the specific social effects of inventions. One of his most famous analyses concerns the invention of radio, for which he listed no less than 150 effects. We provide some extracts, with the numbering assigned by this author, in Box 1.1.

**I. On uniformity and diffusion**

5. Distinctions between social classes and economic groups lessened.

9. Favoring of the widely spread languages.

**II. On recreation and entertainment**

14. The enjoyment of music popularized greatly.

20. Revival of old song, at least for a time.

**III. On transportation**

27. Radio beams, enabling aviators to remain on course.

34. Receipt of communications en route by air passengers.

**IV. On education**

38. Broadcasting has aided adult education.

48. Discussion of books aids selection and stimulates readers.

**V. On the dissemination of information**

56. Prevention of loss in crops by broadcasting weather reports.

64. Quicker detection of crime and criminals, through police automobile patrols equipped with radio.

**VI. On religion**

65. Discouragement, it is said, of preachers of lesser abilities.

68. Invalids and others unable to attend church enabled to hear religious service.

**VII. On industry and business**

79. A new form of advertising has been created.

84. An increase in the consumption of electricity.

85. Provision of employment for 200,000 persons.

**VIII. On occupations**

89. Music sales and possibly song writing have declined. Studies indicate that broadcasting is a factor.

92. New occupations: announcer, engineer, advertising salesman.

**IX. On government and politics**

98. New problem of copyright has arisen.

100. Executive pressure on legislatures, through radio appeals.

**X. On other inventions**

120. The vacuum tube, a radio invention, is used in many fields […] A new science is being developed on the vacuum tube.

125. Geophysical prospecting aided by the radio.

**XI. Miscellaneous**

132. The noise problem of loud speakers has caused some regulation.

135. Late hours have been ruled against in dormitories and homes.

**Box 1.1.** *The effects of the invention of radio (source: Ogburn, 1933)*

While determinism is no longer popular in academic circles – we will see its limits later on (see section 1.1.1.4) – this approach remains surprisingly prominent in public discourse, despite (because of?) its reductionism. Judging by the questions encountered in the press and in widely circulated books, at random: “what is the impact of ICT on business performance?”, “what are the effects of digital technologies on employment?”, “what is the influence of the Internet on doctor-patient relationships?”, etc.

Basically, this approach does not, in itself, make any value judgments about the effects of technology. This is not the case for some of its orientations, which we will now discuss. Some are very enthusiastic about the latest technologies (“promising technology”). Others are resolutely critical of one or all technologies (“technology that causes much harm”).

#### 1.1.1.2. *Technology, which holds promise*

This “techno-enthusiastic” approach nurtures a glorifying vision of technology and praises new technical objects. For its supporters, the source of social progress must be sought in innovations and mainly in material inventions and discoveries, which would occur more quickly and cumulatively than intangible innovations – it should be noted that no evidence has been produced in this regard.

The engineer’s desire to register his/her invention in the world by sharing his/her passion with as many people as possible and the merchant’s desire to disseminate the new technical objects as widely as possible are united in the same fervor. So a technophile euphoria is expressed when announcing all the new features. We recall the communicative utopia celebrated in the late 1960s by media theorist Marshall McLuhan (1911–1980), famous for his notion of the “global village” and his famous formula “the medium is the message” (McLuhan, 1967).

In the 1990s, a new utopia of communication emerged around the notion of cyberspace, exalting collective intelligence and the potentialities of virtual worlds. A representative figure of this trend is that of the philosopher Pierre Lévy (Lévy, 1994).

In a report submitted to the Council of Europe entitled "Cyberculture", it is written:

> "[…] I claim that cyberculture can be considered as a worthy (though distant) heir to the progressive project of 18th Century philosophers. Indeed, it values the participation in communities of debate and argumentation" (Lévy, 1997, p. 302).

Each new feature feeds the techno-enthusiasts. In the 1980s, pioneering authors in the cognitive sciences, such as Douglas Hofstadter (2000) and Marvin Minsky (1990), with widely published books, praised the possibilities of simulating, and stimulating, the brain through computers. These authors have, at least indirectly, fueled the vision of a spiritual fusion between man and machine, preceding the transhumanist wave (see an illustration in Box 1.2).

> Liao and his fellow philosophers, specialists in bio-ethics, raise the problem of climate change today, which can seriously affect life on our planet. Diagnosing the limits of ordinary remedies (hybrid cars, carbon pricing, etc.), they propose new, more radical solutions that consist of manipulating beings to make them more energy efficient. Their recommendations are based on human engineering, which they define as a biomedical modification of individuals in order to make them better able to mitigate climate change. Suggested interventions range from pharmacology, making humans intolerant to meat consumption (18% of global greenhouse gas emissions come from livestock), making humans smaller, by reducing the size of newborns, through drugs, to changing children's growth rates (the ecological footprint is partly correlated with size). Another set of measures, designed to make ecological issues more sensitive, also concerns the use of drugs and genetic modifications. The overall logic is that humans must be manipulated to save the climate.

**Box 1.2.** *Transhumanism to help the environment (source: Liao* et al.*, 2012)*

The prestige of technological modernity attached to a particular technical object is shifting as the corresponding market develops and its purchase price and operating cost fall. This was the case in the change from horse-drawn carriages to cars, from fixed phones to mobile phones, from phones to the Internet, etc. All these "novelties" were, at their release, the prerogative of a few privileged people. Today, 3D printing, "augmented reality", artificial intelligence and biotechnologies, in turn, convey new promises: a world in which any object can be manufactured quickly and anywhere, for 3D printing; the disappearance of screens and omniscience in real time, with augmented reality; personal assistants helping us in daily life, interacting with us, whatever our language, with artificial intelligence; completely restoring or even improving the human body, with biotechnologies.

#### 1.1.1.3. *Technology, the cause of many harmful effects*

Faced with the praiseworthy vision of techno-enthusiasts, a critique of technical thinking has developed, carried by those who are generally referred to as technophobes. Far from being marginal, mistrust of technology is widespread among HSS authors. As the philosopher Jean-Yves Goffi rightly points out: "The list of authors who have emerged from the long list of contemporary technophobes is almost infinite". (Goffi, 1988, p. 11). Contrary to technological consumerism, "technocritics" (Jarrige, 2016) share most of the deterministic assumptions, but strongly contest the idea that technology is the mother of the social progress it would bring forward.

This current of thought is far from being reducible to the posture of a few conservative intellectuals. Long before the development of philosophical criticism of technology, it is necessary to note the social conflicts that marked the beginning of the 19th Century in the context of the industrialization of most European countries, particularly in the textile industry. In France, there were the successive revolts of the *Canuts lyonnais*, rebelling against their working conditions, as well as against the machines that competed with them and deprived them of their livelihood by taking work from their very arms. In England, at the same time, it was the Luddites that came to the fore. To those for whom the triumph of mechanization was inevitable, the struggle of these textile workers, "machine breakers" (the Luddites owe their name to the young Ned Ludd, an apprentice who broke a loom), may have seemed to express an unhealthy and retrograde rage.

But, as the British historian Edward P. Thompson (1963) wrote:

> "The character of Luddism was not that of a blind protest, or of a food riot (as took place in many other districts). Nor will it do to describe Luddism as a form of 'primitive' trade unionism. […] the men who organized, sheltered, or condoned Luddism were far from primitive. They were shrewd and humorous; next to the London artisans, some of them were amongst the most articulate of the 'industrious classes'."

Today, some people claiming the ravages of technological progress and the unemployment induced by automation do not hesitate to accept an identity as neo-Luddites. For example, Chellis Glendinning (1990), a psychologist from New Mexico, published a neo-Luddite manifesto in an alternative press magazine, where she wrote: "The technologies created and disseminated by modern Western societies are out of control and desecrating the fragile fabric of life on Earth." This point of view is far from being isolated (see section 1.3).

In North America, the anti-technology movement is at the root of militant activism that can take extreme forms, sometimes simply spectacular, sometimes very violent. The American essayist Kirkpatrick Sale, author of a vigorous anti-industrial critique (Sale, 1995), made his name with a stunt to smash a computer during the public presentation of his book on the Luddites. From 1978 to 1995, mathematician Theodore John Kaczynski, nicknamed "unabomber", after a promising early career as a professor at Berkeley, committed a series of bomb attacks against the technological society.

In France too, there are many examples of neo-Luddite actors. Some of them have been in the news in recent decades. A mysterious group, CLODO (*Comité Liquidant ou Détournant les Ordinateurs* – Committee for Liquidation or Subversion of Computers), committed arson against computer companies, in the Toulouse region, between 1980 and 1983. In 2005, three young people, including a philosopher known for her translations of critical works on modern technology, destroyed two biometric terminals in a high school cafeteria with a hammer. Similarly, we can consider as inspired by the neo-Luddite spirit the movement based around the ZAD (*zone à défendre* – Zone to Defend), the most famous expression of which was the one erected on the site of Notre-Dame-des-Landes against an airport project.

**Box 1.3.** *Neo-Luddism today*

#### 1.1.1.3.1. Fear of job destruction

Among workers, fear of job loss mainly fuels the rejection of technical innovations. Herbert Simon, 1978 Nobel Prize winner in economics, reports that, long before the artificial intelligence of which he was a pioneer, the argument against mechanization has always been that it was a cause of unemployment. He illustrates his point by referring to the almost total disappearance of the horse on farms at the beginning of the 20th Century in the United States. So, he wonders: can the same thing happen to the human worker? (See Box 1.4.)

> "In 1915, the horse population in the United States reached a peak of about twenty-one million head. By 1960, it had fallen to two million and almost no horse was a draught horse. Facing the tractor, the horse was simply not able to produce enough to pay for its maintenance […]. A man, a horse and a plough could still plough several acres a day, as in the past. But the tractor had increased the costs of the driver whose productivity was higher when ploughing with a tractor. At the new real salary that man could demand thanks to the invention of a mechanical substitute, the horse could no longer cover the cost of his services."

**Box 1.4.** *The horse, the human and the tractor (source: Simon, 1980)*

For Simon (1980), as for the other economists we quote in our general introduction, technological progress is entirely compatible with full employment. However, the theory of job-destroying technology continues to be supported. As early as the 1950s and 1960s, some argued that in a high-tech economy, only the most educated would get a job. When, in the late 1980s, word processing machines and then the first microcomputers, known as "new office technologies", invaded companies, some alarmist studies believed that secretaries had disappeared, given the performance of equipment and the productivity gains announced. This was not the case. In the mid-2000s, it was the progress of robotics in the industry that was generally singled out and renewed the fears of the past (we will return to this in Chapter 3).

Many of the effects attributed to technological change are due to a combination of factors and not technology alone, and in any case, not to a single technical object. To continue the illustration given in Box 1.4, Cépède *et al*. (1951) note that in the United States, the number of agricultural workers declined by about one-fifth between the end of World War I and

1944. However, according to American agronomists, only 14% of this result is attributable to tractors, while, during this period, the number of tractors increased from 200,000 to 2,200,000. The 48% reduction in employment was certainly achieved through the use of machines (trucks, cars, milking machines, electric fences, etc.) but not only the tractor. The remaining 52% was due to the implementation of a streamlined organization that resulted in higher yields per hectare and reduced useful working time, as well as an increase in the size of agricultural holdings.

What about today, with the emergence of new technologies such as artificial intelligence, robots and chatbots, software programmed to simulate a natural language conversation with a consumer or other individual? The most common answer is that if these technologies kill jobs – the least skilled because they are most likely to be automated – they create new ones.

With regard to the introduction of robots into industry, a sector in which there is some visibility as opposed to services, a report by the International Federation of Robotics (IFR) (2018), an association of industrial and service robot manufacturers, underlines that the world industry spent $16.2 billion on robots in 2017, a 21% increase over 2016. And, according to the same sources, during 2018 at least 421,000 new robots were installed. And in 2021, this may be 630,000 robots, almost double the record set in 2017. There is therefore a legitimate concern that the automation of production lines could put workers on the sidelines. However, according to IFR, industrial robots can have a positive impact on employment, although job profiles and skill requirements will be modified (see Chapter 3).

#### 1.1.1.3.2. Criticism of technicist ideology

Another criticism, an intellectual one, is directed at the technicist ideology. Jacques Ellul (1912–1994), a thinker of technological society and modernity, inspired by Marx's thinking, was the leading figure in the critical analyses of technicist ideology, underlining both the inexorable nature of technology and the damage of technical euphoria.

In *La technique ou l'enjeu du siècle* (Ellul, 1954), it is considered that technology now includes civilization because, as the author argues, we are no longer with technology, but in technology. Later, Ellul took this conception further, stating that technology had ceased to be an addition of techniques and became a "technician system" (Ellul, 1977). This system has developed to such an extent that the human being has lost all contact with his/her natural environment and has no more relations than with this mediator. For the philosopher, it is now an autonomous system of techniques, because it has become a primary factor that imposes its laws on all humanity: "Beyond a certain degree of technicization, we move from a society determined by natural factors to a society determined by technical factors" (1977, p. 77).

About 10 years later, Ellul (1988) radicalized his remarks with the shock formula of "technological bluff". In the book that bears this title, he argued against the fact that the technocratic discourse invests in technologies with many uses, considerably exaggerating their actual possibilities, while radically obscuring the negative aspects (costs and dangers). Technology, he believes, is now presented to us both as the only solution to all our collective or individual problems, and as the only opportunity for progress. The "technological bluff" theory has become topical again in recent years during the debates on nuclear energy following the Fukushima disaster (see Box 1.5).

A physicist, Bernard Laponche, involved in the development of the first French power plants and now an activist for the development of renewable energies, recently protested against the idea of nuclear power as a highly sophisticated technology. Interviewed by a journalist, he said:

"A nuclear reactor is only a boiler: it produces heat. But instead of heat, as in thermal power plants, coming from the combustion of coal or gas, it is the result of the fission of uranium […]. Nuclear energy is therefore not this miraculous thing that would see electricity 'coming out' of the reactor, as if there were an almost spontaneous production…"

**Box 1.5.** *The technological bluff theory (source: comments collected by Vincent Remy - Télérama no. 3205)*

Politician Lucien Sfez (2002) also notes the increase of the discourse on technology and questions its sources of legitimacy, concluding that his positions owe nothing to the knowledge of experts. According to Sfez, ideological issues are hidden behind technical objects, supposedly carriers of rationality and progress. To illustrate technological myths, he gives the example of the role played by technology in the reform of French telecommunications, in which decision-making processes have become communication processes. Thus, he explains that technology is first national and egalitarian, impregnated with “public service”, embodied by a large body of technical civil servants (telecom engineers); then, the marks of the technology are erased to be able to sell it in response to expectations of happiness and comfort. Finally, an advertising sign system is set up to promote a future, open to innovation. The debate on structural reform and the change in status is being replaced by a corporate image promotion carried out through an advertising campaign (“*un avenir d’avance*” (a future in advance) was France Telecom’s slogan at the end of the 1980s).

#### 1.1.1.3.3. The rejection of technical domination and the risk of dehumanization

Michel Foucault (1926–1984) and his concept of a “surveillance society” (Foucault, 1975) have been a source of inspiration for all those who postulate technical domination. To characterize disciplinary power, Foucault cites the penitentiary project of Jeremy Bentham, an 18th Century English reformer: the panopticon. This prison structure is a control system that ensures continuous surveillance of individuals without them knowing when they are observed. Surveillance is omnipresent, yet hidden, so that prisoners in the prison exercise self-discipline and incorporate the behavioral standards expected of them. For some, the surveillance society is, in a way, the dark side of the information society, which is expressed through the proliferation of a security apparatus that is constantly being improved: video surveillance, geolocation, biometrics, etc.

Building on this work, Sewell (1998) examined the coupling of the informatization of production processes and new organizations of work in autonomous teams. He states that these two devices increase vertical (by information systems) and horizontal (by partners) monitoring. Everything encourages the development of self-discipline, the development of which follows the same mechanisms as the panopticon.

In addition to political criticism, some add a psychological critique, that of the risk of dehumanization. For Sherry Turkle (2015), new technologies are redefining our emotional lives and intimacy. From a wide range of observed situations, Turkle describes the general conditions under which digital communications can have a resolutely negative influence on interpersonal relationships. They undermine self-reflection and ultimately degrade well-being. She argues that communication technology, always changing, distracts us from important social experiences here and now. For example, mobile phones can divert attention from face-to-face conversations by highlighting concerns about maintaining broader social networks.

In another order of criticism, Francis Pavé (1989) develops the theory that computer science, although not determining social organization, conveys a particular way of thinking, "hyperfunctionalism", which refers to a logical-mathematical model of a reality. The purified, coherent and rationalized reality that results from automated data processing gives the illusion of being the bearer of an organizational project that is imposed on everyone. Hyperfunctionalism postulates the primacy of logical reason, an ideology of total transparency that makes an actors' behavior predictable, and which can therefore be manipulated.

This transparency has a market value, but it also has a social cost. For Zuboff (2015), it is the mark of a surveillance capitalism based on the giants of the Web who are the main providers of practices that endanger our private lives. They monitor individuals, particularly users of digital services, and make their behavior predictable and therefore controllable.

#### 1.1.1.4. *Contributions and limitations of technological determinism*

The posture of techno-enthusiasts has brought about the idea of progress and directed the attention of individuals towards a promising future. But the exaltation of which it is the source is not without unfortunate consequences. Moreover, as the American historian Jeffrey Herf (1986) has shown with regard to Nazi Germany, material modernity can very well be accommodated by a reactionary ideology, far removed from the idea of progress; at the very least, adherence to technological modernity is not a guarantee of emancipation.

Technocritics are also to blame, in the excesses of their radical contestation of technosciences. Nevertheless, unlike technophile proselytism, which tends to mask the harmful effects of technology in the name of progress and its requirements, criticism of technology has the advantage that it questions the technological phenomenon, revealing its hidden face, and "denaturalizes" it. However, it does not provide instructions for its use and, in its exaggerations, it can slow down the progress of a society.

The rejection of technological determinism is not only fueled by the excesses of its two opposite sides. More substantially, it is the irremediability of the technology that is in question and, in particular, its supposed dependence on science.

In fact, technologies, which have their own rationality, are not reduced to scientific applications. Technical gestures are underpinned by representations that are not necessarily part of scholarly knowledge. Moreover, technology develops independently of science; the proof is the architect's empirical know-how. In this field there is indeed knowledge, but this knowledge is not the knowledge that is derived from a particular science. Moreover, if we can go from science to technology, it is quite possible to do the opposite. Science is indebted to technology whenever practice advances theory, for example the case of the steam engine, which owes its birth to the tricks of mechanics whose practice contributed to the development of thermodynamics, which prior to that did not exist (Daumas, 1963).

### 1.1.2. *Social constructivism*

In contrast to technological determinism, social constructivism takes many forms. For our limited purpose, we want to refer simply to approaches that, rejecting technological determinism, question the way in which technical objects are socially constructed. Consequently, this approach examines why and how social functioning influences technological change.

#### 1.1.2.1. *Technology, always subordinated to society*

The idea of technological determinism, which could be thought to be inspired by the metaphor of contagion in medicine (evolutionary model) or the ballistics of artillerymen (ballistic model), has always been a controversial issue. As a counterpoint, there is a social constructivism based on the following assumptions, more or less asserted according to the currents of thought:

– social structures determine technological change;

– there are technical alternatives, depending on social expectations;

– technology does not determine anything by itself; it always gives the actors room for maneuver;

– the notion of impact is to be rejected, because everything depends on the way in which technical objects (uses) are used.

This point of view does not deny that technology entails choices and orientations. Some authors have come to argue that it is the social relationships embedded in the technology that are imposed on the users of it.

This conception deeply questions the autonomy of technology, since it considers it only as a transmission medium for the representations of those who promote it. The media coverage of economic, political or other projects via a technology that serves as a relay is not without implementation difficulties, such as those raised by integrated management systems (see Box 1.6).

Despite their adaptability and customization, enterprise resource planning software packages (SAP, Oracle, Baan, PeopleSoft, etc.) are based on specific organizational models. SAP R/3, released in 1993, comes from the Material Requirement Planning (MRP) systems for calculating component part requirements in the German mechanical industry. It is the structure of this industry, its organizational modes in force in the 1970s and its production modes that have been included in the software, making it much less suitable for flow industries or those where the number of elements to be supplied is lower, or even for service companies for which it introduces complexities which are of no use. The efforts of integrators to transform the organizational reality they are confronted with, in order to move towards an ideal model that promotes the "best practices" formalized in the software package, face important limitations.

**Box 1.6.** *A controversy over integrated management systems (source: Gilbert and Leclair, 2004)*

In the end, it is the organizational actors who interpret the elements applied to them and who, through their interaction and according to various strategies, reach a certain state resulting from technological change. When the weight of the technical factor is reduced to the extreme (radical version), this approach takes the form of a kind of social determinism, or at least the determination of technological change by the social factor.

#### 1.1.2.2. *A moderate version: in the face of technicism, the interplay of social actors*

Developed by Michel Crozier (Crozier, 1964; Crozier and Friedberg, 1977), the strategic actor theory is one of the foundations of a moderate approach. For them, behavior in a situation of technological change does not result from technological determinisms but from the strategic intentions of social actors who aim to achieve certain goals. In other words, technology is always subject to the verdict of its users and the logic of negotiation always prevails over instrumental rationality.

The formulation of this theory is largely based on a critique of contingency theory and specifically technological determinism (Crozier and Friedberg, 1977, Chapter 4, Section 1). This relativization of the influence of technology is a sociological tradition that can be found markedly in work specifically related to information science (e.g. Pavé, 1989, or more recently, Segrestin *et al*., 2004).

Concerning the computerization of companies, the work of sociologists, often working in teams with economists, has been particularly visible in France. They generally conclude that while technologies are a variable that influence the organization and conditions of work, they are by no means the only and determining factor (Bernoux, 2004). Among the surveys carried out, we describe in Box 1.7 some conclusions from a report supported by a statistical survey on the link between ICT (information and communication technologies) and working conditions. This theme has particularly fueled the social debate around the increase in suffering at work.

> The study takes into account ICT, emblematic of the knowledge economy, whether in terms of hardware equipment or specific software: network technologies, integrated management systems, process modeling tools, collaborative work, traceability or automatic distribution of telephone calls. In addition to equipment, it examines employees' uses of these technical objects, distinguishing between the uses of highly connected employees and those of employees who are not or only slightly connected. The statistical study analyzes the working conditions of employees according to these practices and the context of their company's equipment.
>
> The statistical analysis reveals two main labor mobilization regimes related to ICT. Connected technologies, used by a "trusted employee", managerial status or intermediate profession in large companies, are associated with a perception of

intensification at work (with spillover into the private sphere), as well as with autonomy and a certain well-being, due to the feeling that work is recognized at its true value. On the other hand, users of technologies that are not or only poorly connected and employees of companies equipped with transversal software tools (ERP, process modeling, traceability tools) and those working in a call center not only have an intense working experience but also little room for maneuver to respond to it, because the prescription can go as far as operating modes (script models to be respected). Their work is controlled, even under supervision (in call centers), even though they have to deal with unclear or contradictory injunctions. Paradoxically, employees who do not use these technologies are subject to the digital divide. Their work is probably less intense, but it is impoverished and finally employees consider it unsatisfactory.

In short, the report shows that the risks allegedly generated by ICT are closely linked to the organizational context in which they are embedded and to the decisions of company management on how IT supports management activity. Therefore, rather than attributing a deterministic role to ICT, the authors of the report conclude that it would be appropriate to reason in terms of risks associated with configurations of contexts and uses.

**Box 1.7.** *The differential effects of ICT on the organization (source: Greenan* et al.*, 2012)*

In practice, the "mechanical" logic inevitably comes into confrontation with another one, that of the social. This results in the "computer conflict" because, as Pichault (1990) points out, the acceptance of a technology, however sophisticated it may be, is always subject to the verdict of its users.

This "externalistic" vision of technology – in that it does not concern itself with the way in which technical objects are manufactured – does not go as far as social determinism, because it rejects any simple determinism.

### 1.1.2.3. *A radical version: the metaphor of ventriloquism*

More radically, social constructivism can be transformed into social determinism. This approach essentially refers to the idea that it is the interactions (debates, negotiations, exchanges, consultations and confrontations) between the actors that ensure that a technology develops and exists through uses. For social determinism, any technological project brings together actors who come together to define the technology, to specify its uses and its effectiveness (Bijker, Hughes and Pinch, 1987). It is therefore society that determines technology.

Technical objects provide a range of implicit functions that help to control and promote the acceptance of a change that is not fundamentally technical. It is not uncommon for technical objects, although not designed in this spirit, to serve as lightning rods, channeling the strong emotions (bitterness, anger, etc.) that inevitably manifest themselves during radical organizational changes. Their implementation is then an opportunity to liquidate problems that could not be addressed head-on, without going through the open conflict and the negative consequences that would result.

Let us return to the typical example of integrated management systems (discussed in Box 1.6). They have been highly criticized for their effects on work and the balance of responsibilities. However, should they be considered as an expression of a new form of difficulty at work and a factor of exclusion? In large companies, at the heart of the tensions that affect business management, the software package sometimes appears as a mediator designed to manage the tensions resulting from the call for the development of autonomy, by more decentralized organizations, associated with the strengthening of control, through the control of information and its processing processes. Integrated management systems have been introduced in companies facing contradictions in strategy, political discourse and effective practices. One of their roles has been to somehow absorb these tensions and contradictions.

As in the case of the integrated management systems just mentioned, it could be said that humans delegate a negotiating role to technical objects. François Cooren (2010) goes further, stating that silent objects speak through their interlocutors. He proposes the metaphor of ventriloquism to express the idea that humans make objects speak, while letting objects speak through them:

> "The advantage of such a metaphor is that it makes it possible not only to identify the beings that the interlocutors animate in their conversations, but also to show that, in doing so, these same interlocutors position themselves as animated by the beings they animate. In other words, the ventriloquist is not necessarily who you think they are…" (Cooren, 2010, p. 41, authors' translation).

This analysis "unmasks" technological determinism by replacing it with social determinism. Thus, today, any major organizational change is argued on the basis of technological imperatives. To say that digital technology imposes a particular restructuring, or that it is the computer application that obliges a particular measure: is this not a way of making the weight of transformation bear on technology, by letting it speak for those who want change and whose intentions no longer need to be debated? "It's the technology that wants that."

#### 1.1.2.4. *Contributions and limitations of social constructivism*

Among the approaches dealing with confrontation, happy or gloomy, with technology and social issues, social constructivism brings with it a notable difference. It has the merit of drawing attention to factors other than those that are strictly technical and yet contribute to technological change (see the example we give above of the motorization on agriculture).

But this approach is open to criticism when it leads to absolute social relativism, affirming the total neutrality of the technology and denying that it can produce effects by itself. The conclusion we could draw from this is that technology is devoid of any structuring action, which would obviously be suspicious.

If we admit that the phenomena traditionally called "impacts" are not really impacts, we must also recognize that the tendency to see in the implementation of a technical object only a pretext or an "opportunity" is just as erroneous. The introduction of new technologies has consequences for both organizations and social functioning. In other words, while technology does not determine much, it is not without effect. It is in this in-between that the following approach takes place.

### 1.1.3. *Joint structuring of technical and social aspects*

In addition to the approaches that represent technology and society in unidirectional confrontational relationships, there are others that, on the contrary, see them as linked, or even confused, the existence of two separate spheres (technical vs. social) being contested.

#### 1.1.3.1. *The anthropotechnical*[1] *perspective: moving beyond the two determinisms*

Emancipating itself from the archetypal opposition between the social construction of technology and the technical construction of society, the theory of the co-structuring of technology and society postulates that there are no simple relations between the two domains, but ambiguous and complex relations. This view can be found in the work of classical philosophers or ethnologists such as Gilbert Simondon, Bertrand Gille or André Leroy-Gourhan.

This approach jointly refutes both determinisms and postulates a double movement. Its main assumptions are as follows:

– technologies only occur in a social context that favors it;

– technology is a cultural fact; each technology conveys a conception of social relations, a culture. Thus, Dagognet (1989, p. 41), inspired by Mauss (1926), argues that the technical object is precisely a “total social fact” that we must learn to read and decipher in order to discover “the cultural that is part of it”;

– technologies are not neutral; they have social effects;

– but not all of them are powerful and their effects are ambivalent.

There are several currents of research here, including the sociology of translation, structuring theory and activity theory.

#### 1.1.3.2. *Sociology of translation and model of seamless fabric*

The sociology of translation (Akrich *et al*., 2006), also known as actor–network theory or ANT, has become a leading reference for the social sciences. In the “seamless fabric” model – weaving between technological environments and systems on the one hand, and social environments and systems on the other – technology and society “[…] emerge together from innovation processes and technology appears only as a particular modality of sustainable association of humans with each other and with non-human entities” (Akrich, 1994, p. 107, authors’ translation).

1 We use “anthropotechnical” rather than “socio-technical” to distinguish from “socio-technical” history, born in the 1950s, marked by the industrial universe and the postulate of a separation between the technical system and the social system.

This emergence is achieved in line with “translations”, a metaphor for the way in which certain actors set themselves up as “spokespersons” for other actors whom they seek to mobilize and interest, in order to associate them within a socio-technical network. If the incentive is successful, there is “enrolment”. Instead of a principled opposition between technical and social, human and non-human (called “actants”), translation chains refer to the work by which actants modify, displace and translate their varied and contradictory interests.

ANT invokes a similar treatment of human and non-human actors, refusing to distinguish between what is social and what is technical (“principle of symmetry”). More broadly, proponents of this current of thought reject the distinctions between science, technology and society. Originally, ANT researchers were interested in the conditions for the production of science and the diffusion of technological innovations and wanted to put an end to the extreme positions that considered either that science and technology were external to society, political passions, cultural prejudices, personal feelings, or that the scientific fact was merely the result of power games. Rejecting this dual vision, they consider that society and technology, human and non-human, do not constitute two distinct worlds; they are closely intertwined and interact with each other. Non-human entities (objects, machines, tools, equipment) and the devices set up to represent them have their own way of life: they produce effects on the course of action, in the same way as humans do.

In order to avoid the pitfalls of “naturalization” (scientific rationality) and “socialization” (social constructivism), ANT seeks to offer a balanced vision of the social construction of our artifacts (products of human activity) and the technical construction of our social ties. While common sense generally recognizes that traditional technologies are the result of social construction, as ethnologists have shown, modern equipment and high technology are often assumed to have a less social, more self-determined way of life. ANT shows that this is not the case.

By considering the subject–object relationship as a process of co-incorporation of the object in the social and the social in the object, it proposes an original way of approaching socio-technical networks. It shows that it is not the intrinsic quality of innovation that imposes it, but the process on which it is based and, in particular, the consolidation and expansion of the network that drives it. In this way, ANT provides useful benchmarks for understanding technological change.

Because of the principle of symmetry, the researcher must give equal importance to both failures and successes:

> "If we say of a successful project that it existed from the beginning because it was well designed and the failed project broke down because it was poorly designed, we say nothing. We are simply repeating the words 'success' and 'failure' by placing the cause of both at the beginning of the project, at its conception" (Latour, 1992, pp. 71–72, authors' translation).

On the basis of this reasoning, one of Latour's research works focuses on the analysis of a failure: that of Aramis, a revolutionary automatic metro that existed until it became a prototype and was abandoned in 1987 by its three sponsors, the State, RATP and the Matra company (Latour, 1992). This case study summarizes the research carried out over many years on the dynamics of innovation and the way it involves technology (see Box 1.8).

Aramis was the development of a public transport project aimed to individualize use (reduction in the size of trains and autonomy of mini-trains in terms of stopping and restarting them). A series of difficult technical problems were gradually solved, but the growing network faced the difficulty of including a group of key players: frail people, elderly people, etc. How could they avoid the accelerations and decelerations that such a means of locomotion would imply? This technical difficulty was a real and lasting problem. However, the inclusion of elderly people was a *sine qua non* condition for the development of the network supporting this technical project. One of the project's engineers proposed a translation: he/she made the analogy between this problem and that of the displacement of explosives sensitive to the same constraints. The translation operation was successful when the resolution tracks that became available in the context of the armaments industry were properly adapted to the context of passenger transport. Any translation is an effective approximation: the different contexts do not, by definition, allow the expression of the same statement (process). Contexts and statements, scientific facts and networks, actors and systems, actions and situations are redefined.

In the end, the Aramis projected failed. Latour shows that human actors must fight, negotiate and discuss in order to make a technical project exist, as that type of project is not similar to a scientific fact whose evidence would be binding. On the contrary, it is made up of doubts, uncertainties and bets on the future and without a total commitment from the actors, it risks dying of weakness. As humans withdraw their support, their vitality, the technique loses what it possessed of humanity and ceases to exist.

**Box 1.8.** *An analysis in terms of a socio-technical network (source: Latour, 1992)*

The most common criticism of this approach is that it is an anthropomorphism of technology. The notion of the actant, equating "human" and "non-human" and assigning strategic capacity to technical devices, has sometimes been perceived as a real provocation and has been the subject of numerous attacks. These are particularly nourished by sociologists of a critical orientation who criticize it for reducing the sphere of politics to the sole adaptation to the requirements of technological change (Metzger, 2011).

#### 1.1.3.3. *Activity theory: no technical objects outside the activity system*

"Activity theory" was developed by Vygotsky (1896–1934), a pioneer of the Soviet historical and cultural school of psychology (Vygotsky, 1997). Vygotsky took from Marx the principle of transformation of the self and the species through the material tools that he considered to be a major psychological fact. In this theory, the genesis of the psyche is achieved through collective activities and the technical mediation of these activities.

Leontiev (1978) took Vygotsky's theory further and sought the elements that make it possible to define the activity for which he proposed a three-level hierarchical structure (activity, action and operations). The activity is driven by a motive and develops gradually, wanting to satisfy this motive, through actions in the real world; the distinction between "activity" and "actions" is therefore fundamental. Actions, which are the product of the transposition into reality of the will to achieve the "motive" of the activity, refer to conscious goals, designed to achieve them. But they are part of the broader context of an activity and the "reason" for it. In addition, Leontiev proposed to break down the actions into "operations" that concretely carry out the actions in the situation. In continuity with Marx, who maintained that the means of work modify humanity's "natural nature", Vygotsky postulated that their appropriation restructures the development of the psyche.

Technical objects are therefore not mere auxiliaries that prolong the human psyche by leaving its mental functions unchanged. On the contrary, they transform its development. Their role is therefore central. But they are nothing outside the system of activity. They only produce effects through internal reconstruction by the subject through social cooperation practices.

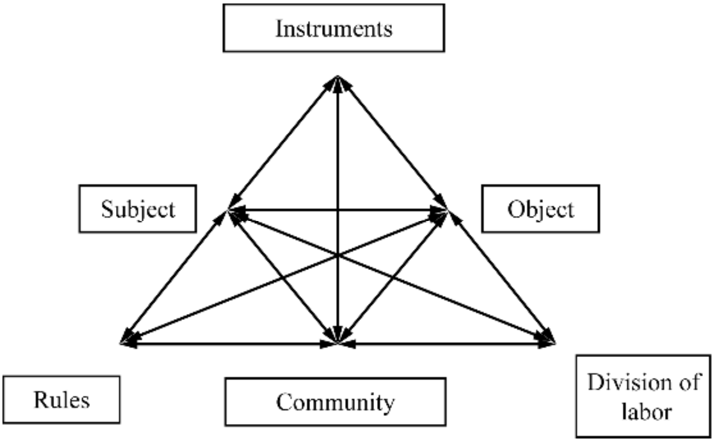


**Figure 1.1.** *Basic structure of an activity (source: adapted from Engeström, 1987, p. 78)*

This theory is used in a wide variety of fields (educational psychology, occupational psychology, ergonomics, didactics, computer science, etc.). It has developed particularly in Northern Europe. Finnish native Engeström (Engeström, 1987, 1999) applied Vygotsky's ideas to the study of interactions and communication at work, focusing on collective activity and the way it is structured.

For Engeström, analyzing an activity means analyzing a system that includes the individual, the tools, the materials or concepts they use, their relationships with the community around them and the product they propose to produce, the interactions that occur there and the transformations that take place there while maintaining a global vision of the system. The individual is not an isolated subject but is part of a community that represents all the subjects who share the same object (task to be performed, objective to be achieved) targeted by the activity. Their own activity cannot be described outside this context. When new members arrive in a community, they must appropriate distributed knowledge. Relationships between individuals and the community are governed by rules (norms, conventions, shared work practices, etc.), implicit or explicit, that maintain and regulate actions and interactions within the system. The activity is carried out by means of instruments, material or not, according to a division of labor (distribution of actions between subjects) and according to production, concrete or abstract.

Starting from the hierarchical structure of the activity and the components of the activity system, Kuutti (1996) applied this model to the analysis of ways to support activities through information technology (see Table 1.1).

| | Level of activity | Level of action | Level of operations |
|---|---|---|---|
| **Tool/instrument** | Supporting transformative and instrumental actions<br><br>Making tools and procedures visible and understandable | Enabling the automation of a new routine or the construction of a new tool | Automating routines |
| **Object** | Making sure that an object becomes a common good | Making an object manipulable | Providing data on an object |
| **Subject** | Supporting learning and reflection in relation to the whole mission and the object | Supporting the creation of meaning in an activity | Initiating pre-established responses |
| **Rules** | Enabling the negotiation of new rules | Ensuring that all rules are visible and understandable | Integrating and imposing a certain number of rules |
| **Community** | Fostering training of a new community | Promoting communication actions<br>Making the network of actors visible | Creating a virtual community by linking the different work tasks of several people together |
| **Division of labor** | Facilitating the redefinition of a division of labor | Making the organization of work visible and understandable | Integrating and imposing a certain division of labor |

**Table 1.1.** *Means of supporting activities via information technology (source: adapted from Kuutti, 1996, pp. 38–39)*

#### 1.1.3.4. *Structuration theory and duality of the structural*

Structuration theory (Giddens, 1987) seeks to shed light on individuals' actions by linking them to the characteristics of the structure of the social system. The term "structural" is used to make reference to an approach to structure that involves dynamic processes. It models the processes by which social systems are produced and reproduced. The notion of the "duality of the structural", central to this theory, underlines that while structures constrain social action, they are also created, modified and renewed by competent actors.

Giddens does not specifically address the link between structuring and technology. But structuring theory is increasingly being used to study the relationships between information systems, human action and social structure. Through this perspective, information systems are conceptualized as human artifacts, produced and reproduced by human actions, and which simultaneously constrain and enable such actions. This approach shares with ANT and activity theory a vision of the contextual and negotiated nature of the links between technical and organizational phenomena. Like the two previous theories, it has made it possible to move away from both technological determinism and an exclusive focus on the behavior of actors by focusing on interactions around technology (Bia Figueiredo and Morley, 2015, p. 48). As such, it constitutes a stimulating entry into the discussion on the impact of new technologies on organizational change.

Stephen Barley and Wanda Orlikowski were pioneers in the application of this theory to the specific field of technology, showing how human actors and organizational structure interact in a structured and structuring process where technology is considered a social construct, both a medium and result of these interactions.

In a seminal article, Barley (1986) analyzes the evolution of interactions within two different radiology units following the introduction of new medical imaging devices, CT scanners. These devices have changed the distribution of roles and skills between radiologists and radiology technicians, thus contributing to the transformation of logical radio work and, beyond that, of organizations. But it also shows how identical scanners that have led to similar structuring processes in two radiology departments have led to divergent forms of organization.

Orlikowski (1992), following on from structuration theory, advanced the notion of duality of technology. In this approach, organizations are not only shaped by information technologies but also strongly influenced by social processes. Technologies are therefore both the product and the medium of human activity. Once implemented, the technology ceases to belong to its designers or promoters and is part of the structural properties of the organization. The ways in which technology is used as a support for action become structural routines that become institutionalized in the organization. Symmetrically, through their reflexive control, actors are also led to change their relationship with technology, intentionally or unintentionally.

### 1.1.4. *Limitation of established distinctions*

To close this section, we can note that most of the authors, including those we have cited, do not fit fully into the categories we have established, which are quite simplistic.

For example, Ogburn, who we cited as illustrating a form of technological determinism, also noted that many inventions had been made in parallel by several inventors who ignored each other and thus defended the theory of cultural determinism: culture will largely determine the possible inventions. Yet Pavé, although supporting the theory of hyper-functionalism in computing (technological determinism), shows that technology does not lead directly to a predefined social organization (social constructivism) because, as he explains, actors have the ability to reshape the devices imposed on them at their convenience.

## 1.2. A brief history of technological change

While technological change is synonymous with topicality and modernity, it has a history. To ignore it would be to condemn oneself to understanding nothing of what is happening with an ongoing change. Nevertheless, the exercise is not self-evident. A summary that would deal with the history of technology in its entirety would be insipid and in any case out of step with the project of the book. The adventure would be perilous: the theories are eclectic; David Edgerton (1998) distinguishes no less than 10, each giving a particular image of technology.

Our intention is, more modestly, to focus on periods of change, rather than those that are traditional and appear more immobile. For a broader and more scholarly coverage of the history of technology, we refer the reader to specialized works, for example, the five volumes of the general history of technology published by Daumas between 1962 and 1979, or the work of Bertrand Gille (1978). It should be noted that syntheses also exist (e.g. Baudet, 2016).

### 1.2.1. *How can we tell the story?*

The above being said, the remaining task is to define a method to talk about technological change and to divide history into significant periods.

As we warned the reader in the introduction, we intend to discuss technologies and their evolution without reducing them to a succession of isolated objects and without separating them from the environment in which they occurred. This because, in a technological change, technology is not the only cause. Its transformation is accompanied by various changes such as those in production and exchange structures, as well as mentalities.

A starting point is offered to us by the concept of a technical system, advanced by Gille, for which the technologies should not be studied in isolation but in a set whose elements form a system. Starting from this idea, Lemonnier proposes a definition of technology as:

> "a set always involving four elements: a material on which it acts; objects ('tools', 'means of work', 'artifacts'); gestures or energy sources (running water, wind, animal power, etc.) that set these objects in motion; particular representations that underlie technical gestures" (Lemonnier, 1991, p. 697).

To say that this set concerns a system is to say that the technologies depend on each other with reciprocal actions. For example, the invention of the jet engine in the 1930s required, in addition to the gas turbine (designed in the previous century), the ability to produce metals resistant to very high temperatures and high precision casting of parts. Technical systems are also dependent on political, economic and social environments; so, it would be more accurate to talk about socio-technical systems. Thus, to return to our example of jet aircraft, it was originally a military project which, after having established itself in this field in the 1950s, revolutionized long- and medium-haul civil air transports to meet the growing needs of passenger transport.

We will use Lemonnier's definition, which seems to us to go beyond technology, in that it connects the physical domain (matter, energy) and the human domain (representations), the object being located at the intersection of these two domains, without forgetting that, as Lemonnier (1991, p. 698) reminds us: "Despite its material dimension, any technology is never anything but objectified thought."

To link the technological revolutions to their economic and social environments, we will rely on the notion of an industrial revolution. Referring to the notion of revolution, we are well aware that we are using a debatable term. This notion refers, in fact, to the idea of a sudden change, a radical disruption, a generalized disruption over a short period of time, moving from one state of technology to another, in an irreversible way. This is far from being so obvious. But let us consider this approach as a convenience of presentation.

There remains the question of periodization. We have selected five stages:

1) the origins of the industrial revolution (from the Middle Ages to the Renaissance);

2) the First Industrial Revolution (from the end of the 18th Century to the beginning of the 19th Century);

3) the Second Industrial Revolution (end of the 19th Century to World War I);

4) the computer revolution (late 1960s);

5) the fifth stage announces the digital revolution (beginning of the 21st Century).

The first period is a starting point, showing that the periods preceding the Enlightenment were not without remarkable technological innovations. The next four (periods 2–5) correspond to the revolutions identified by Klauss Schwab (2017), the founder and president of the World Economic Forum. The question of whether there have been three or four industrial revolutions is a matter of debate. Among various renowned personalities, the futurist Jeremy Rifkin includes our periods 4 and 5 in a Third Industrial Revolution that began at the end of the 20th Century (Rifkin, 2012). The advantage of Schwab's periodization is that it focuses on the most recent transformations. That is why we will keep it.

For each period, to describe technological developments, we will mainly consider four descriptive dimensions, from the most material to the most immaterial: materials, energy sources, technical objects and underlying representations (production methods, key disciplines). Each revolution, which we will illustrate with a figure, is characterized by a simultaneous change of these four closely related dimensions. We will place technical objects in the center, because they are the most visible and most related to uses. But it is obviously by relocating the windmill, the steam engine, the car, the computer or the digital networks in their respective environments that we can see a coherent socio-technical system emerge. We will therefore develop our discussion by taking into account the environmental transformations.

### 1.2.2. *At the origins of the Industrial Revolution (from the Middle Ages to the Renaissance)*

It is customary to consider that the industrial revolution dates back to the 19th Century, but historians (White, 1969; Gille, 1978; Gimpel, 1975) now widely admit that the medieval West experienced unprecedented economic development.

The medievalist Jean Gimpel (1975) even claims that the industrial revolution originated in the Middle Ages. Indeed, contrary to the widespread idea of a dark and lethargic age, it was a fertile period of inventions and technological advances. This era revolutionized the world of work through the renewal of energy sources and technological innovation. According to Gimpel, a first "industrial" revolution occurred in the 11th, 12th and 13th Centuries, the emergence of which was specially based on the ability to develop the efficiency of technologies: water mills, camshafts, rigid harnesses and horseshoes, navigation tools, clocks, etc. The adaptation of all these technologies led, at the time, to a spectacular increase in the energy available to economically replace human strength. According to the medievalist, it was on these discoveries, much more than on those of the Renaissance, that the industrial revolution of the 18th Century took off. It is also in the second half of the 12th Century that, according to Crosby (2003), quantification and measurement developed significantly, as deliberate and organized activities that contributed to the constitution of Western rationality, applying measurement to all things, especially chronometry (clocks). The interest in quantification gave rise, from the end of the 13th

Century, to double-entry bookkeeping, which had such an influence on trade and business life, first in large Italian cities and then elsewhere, and which the German sociologist Werner Sombart (1843–1941) said was one of the conditions for the emergence of capitalism.

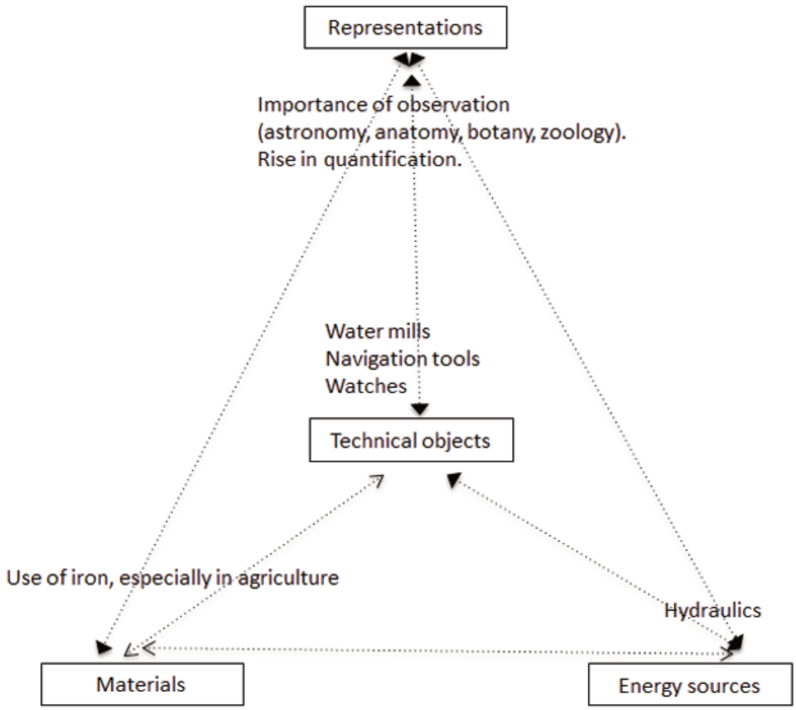


**Figure 1.2.** *Transformation of the socio-technical system in the Middle Ages*

During the 14th and 15th Centuries, there were no major technical developments and, according to Gimpel, Renaissance engineers themselves would only exploit inventions that already existed. However, we cannot overlook the contributions of the Renaissance, particularly with the Italian school and personalities such as Leonardo da Vinci (1452–1519), who made contributions in a wide variety of fields, such as weaponry – a development that went hand in hand with the incessant wars fought by the nations at that time – architecture, metallurgy, textile machinery, watchmaking, hydraulics, etc. (Gilles, 1964). This period was also the time of a new scientific and technological spirit, in which the method of observation spread to all fields such as astronomy (Galileo, 1564–1642), anatomy, botany and zoology. The discoveries were not limited to Italian engineers. For example, Queen Elizabeth I's doctor William Gilbert (1544–1603) is considered the first electrician because of his work on magnetism. Finally, the Renaissance saw the emergence in Europe of a literary and artistic movement which, by drawing on the source of Greek–Latin antiquity, placed the human being at the heart of its concerns.

### 1.2.3. *The First Industrial Revolution (end of the 18th Century)*

In its early days, the First Industrial Revolution was mainly located in the United Kingdom. It extended to other countries much later, in the middle of the 19th Century. It was mainly driven by the development of coal mining and the development of the steam engine by the Scot James Watt in 1769. After 1800, other engineers improved the system even further. The steam engine then arrived and came to be used more and more in industry. These developments made it possible to mechanize production, particularly in the textile sector, for which Edmund Cartwright developed the very first mechanical loom in 1789. In the steel industry, the use of coke became widespread and enabled the construction of blast furnaces. Metallurgy progressed, with coke cast iron, then steel containing less carbon than cast iron, and therefore more resistant, which gradually tended to replace it.

The first machine tools, mechanical equipment that transforms iron (drilling, boring, cutting, etc.), also date from this period. They enabled the manufacture of all kinds of mechanical parts: screws, gear wheels, rods and cylinders. In 1751, Frenchman Vaucanson designed the first turning machine with a mechanical frame, which allowed the precise machining of parts up to 1 m long. Gradually, machines, grouped in vast buildings (ancestors of factories), replaced the work of craftsmen.

At the same time, infrastructures such as waterways, steam transport by sea, and railways came to be developed. However, land transport was still largely dependent on animal power. It was not until 1804 that a steam train ran in Pen-y-Darren, a mining region of Wales known as the Black Country, due to the profusion of coal mines and air pollution. The first railway line was built near Newcastle in 1825. During this period, international trade intensified, supported by the gradual elimination of piracy that had begun, first in Europe at the beginning of the 18th Century and then around Africa and the Indian Ocean.

Mechanical energy also led to the industrialization of printing and, with it, of the written press on a large scale, as well as the dissemination of knowledge. This led to a real inflation in print production (newspapers, administrative printed matter and books) in response to the growing need for information among a readership that was constantly expanding with the progress of literacy.

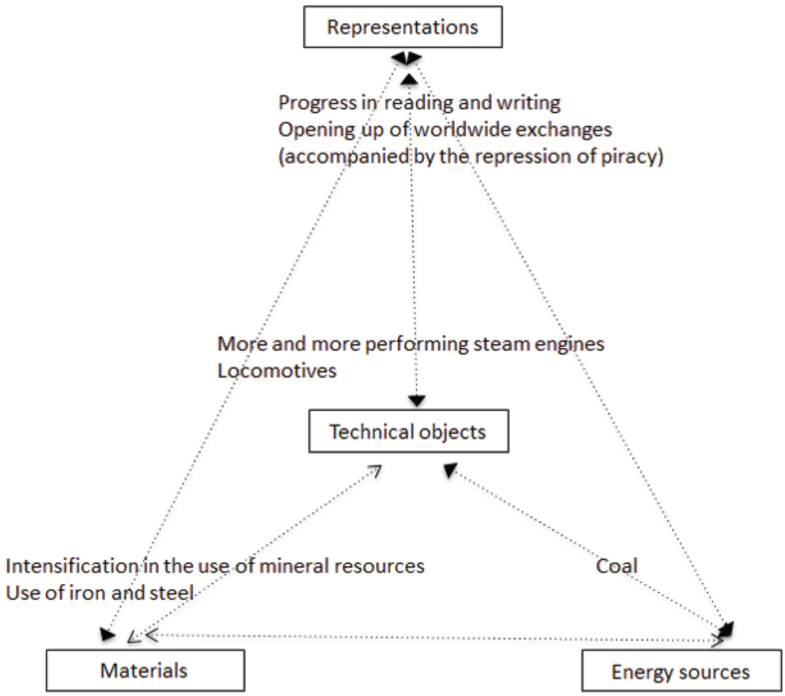


**Figure 1.3.** *Transformation of the socio-technical system during the First Industrial Revolution*

This technical approach should not lead us to forget other changes of magnitude. Particularly noteworthy is the "demographic revolution" and the considerable reduction in the number of illiterate adults, two phenomena highlighted by Rioux (1971). Rioux notes that between 1750 and 1850, the

European population increased from 140 million to 266 million and, in North America, from about 3 million to 40 million. European population growth, mainly due to the fall in mortality rates – boosted by an increase in agricultural productivity that allowed food shortages to disappear – continued in the following period, with the progress of medicine and the end of the major waves of epidemics. Population growth and rising knowledge levels significantly contributed to the development of industry.

### 1.2.4. *The Second Industrial Revolution (late 19th Century to the 1910s)*

The Second Revolution used new energy sources: oil and electricity. Electrical energy enabled the industry to engage in mass production. Oil replaced whale oil as a fuel for lighting and contributed to the development of the automobile that appeared at the end of the 19th Century. The first American oil well was drilled in 1859 by Edwin Drake. This event led to the black gold rush. In 1870, John D. Rockefeller founded Standard Oil, which would hold 80% of the refining and 90% of the transport of "black gold".

Means of transport started to boom. Railroads extended with the opening of a transcontinental link in the United States, from California to Nebraska (in 1869) and the Trans-Siberian Railway (in 1904). Railways provided important opportunities for industry: from 38,000 km of railways worldwide in 1850, to 300,000 km in 1870, to 1 million km in 1914. It also facilitated the circulation of people and ideas. Trade relations and more distant exchanges intensified with maritime shipping. The opening of the Suez Canal (1869) linking the Mediterranean to the Red Sea and the Panama Canal (1914), which directly runs from the Atlantic to the Pacific, created new shipping routes that shortened distances. The emerging automotive industry developed at high speed. There were 4,000 motor vehicles in 1900. The commercial launch of the first Ford T took place in 1908, and it heralded the era of mass production with assembly lines. There were nearly two million cars on the road in 1914.

In addition, new means of communication such as the telegraph and telephone were developed. Samuel Morse filed the patent for the electric telegraph in 1840. The first transatlantic link dates back to 1866 and, in 1870, the European telegraph network covered 500,000 km. In 1876, the telephone, attributed sometimes to the Italian Antonio Meucci, sometimes to the American Graham Bell, who filed the patent, also helped to facilitate remote exchanges.

This period was marked by a relative balance in terms of the economy and international politics (no major wars). It also saw the decline of the agricultural population. Between 1850 and 1910, the numbers of farmers fell from 22% of the active population to 6% in Great Britain, from 64% to 42% in France, from 65% to 18% in Germany and from 65% to 33% in the United States.

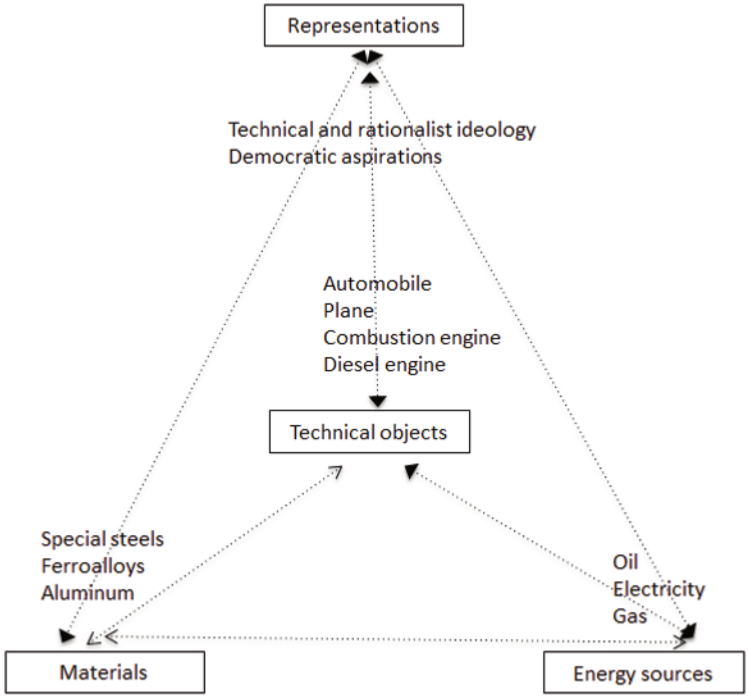


**Figure 1.4.** *Transformation of the socio-technical system during the Second Industrial Revolution*

Utopian rationality also asserted itself at the end of this period when the principles of the scientific organization of work (Taylor, 1911) emerged, which, going beyond the factory, extended its application to domestic work with the American "domestic science" movement at the end of the 19th Century (Frederick, 1912).

The American brothers Wilbur and Orville Wright made the first successful airplane in 1903. But the beginnings of civil aviation concerned only adventurous sportsmen and women, and it was not until the late 1930s that transatlantic commercial flights began.

In conjunction with these flowering inventions, it is necessary to note the emergence of new forms of professional activity. Employers were different from 18th Century traders and manufacturers and more closely linked to finance, but they were less politically powerful since the introduction of universal suffrage (established during the 1848 Revolution). Above all, a numerically important working class emerged that became a social force with which political power needed to deal with.

### 1.2.5. *The Computer Revolution (from the late 1960s to the 1990s)*

At the end of the 20th Century, a third industrial revolution took place, based on electronics, telecommunications and information technology. It was the advent of ICTs.

The first foundations of the IT revolution were laid at the very end of the 1960s and early 1970s. In 1972, Intel launched its 8008 microprocessor on the market. The Apple II, ancestor of the desktop computer, the first to be sold on a large scale, was launched in 1977. IBM's PC (Personal Computer) was launched in 1981. In 1985, IBM employed 10,000 people in its PC division. ARPANET (Advanced Research Projects Agency Network) was created in 1969. It prefigured the Internet computer network and the most famous aspect of the Internet today, the Web (abbreviation of World Wide Web), created in the early 1990s.

After a focus on hardware, companies in the IT sector gradually focused on application software. In industrial sectors, applications were often specific, but the same cannot be said for management areas where automation needs were similar from one company to another, especially when activities were standardized. In fact, accounting software was first developed, an area where the workload was considerable and many retail tasks were relatively simple.

ICT played a major role during this period, accompanying the development of organizational structures. They helped to initiate a profound reconfiguration of production processes and work organizations. The large centralized organizations of the 1960s with information systems driven by mainframe computers were replaced by more decentralized structures with microcomputers. The widespread dissemination of electronic messaging in the late 1980s helped to foster lateral relationships and reduce hierarchical burdens.

Since the end of the 19th Century, the main source of energy has been electricity, produced in power plants. On December 20, 1951, the United States used nuclear energy to generate electricity for the first time. Since the first connection of a nuclear power plant to the electricity grid, the world's nuclear capacity has steadily increased.

This was also the time of the space conquest that inspired a whole generation and illustrated the competition between the United States and the Soviet Union for several decades. On April 12, 1961, the Soviets launched a man into space for the first time. On July 20, 1969, the American Apollo XI mission landed two men on the moon: Neil Armstrong and Edwin Aldrin. Humanity was entering the space age in a spectacular way. On April 12, 1981, the world witnessed the very first flight of the American space shuttle, Columbia.

Finally, this period can also be described as revolutionary from a social point of view. The year 1968 was the year of protest almost everywhere in the world with a social and societal movement of an exceptional magnitude: the Prague Spring in Czechoslovakia, May 1968 in France, American students protesting against the Vietnam War, etc. This year marked the beginning of the decline of traditional institutions and announced the years of reform that would follow and the liberalization of morals.

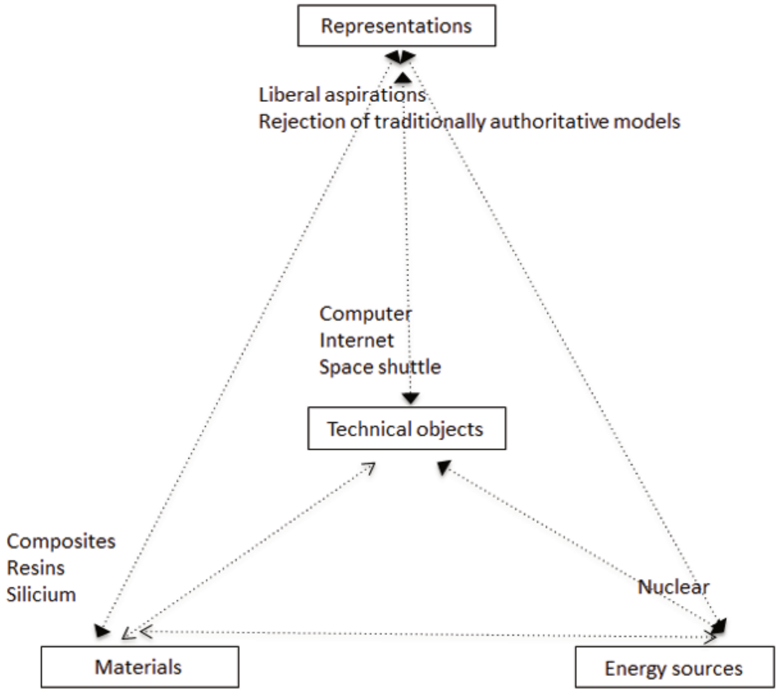


**Figure 1.5.** *Transformation of the socio-technical system during the IT revolution*

### 1.2.6. *The Digital Revolution (early 21st Century)*

We will now look at the current period and its possibilities. The way we look at it differs since we are no longer following a historical analysis, but using prospective studies. Moreover, as we have previously written, not all authors agree that this should be a new era.

For Schwab (2017), on whom we will rely, there is no doubt that the many innovations that have emerged since the beginning of the century constitute a new industrial revolution. This author puts forward three arguments to support his point of view: the speed of the phenomenon, its scale and its impact, which together herald the complete transformation of production, distribution and management systems. In his book, he highlights 23 "profound changes" expected by 2025, highlighting their positive impacts, but without overlooking the difficulties (see a selection of 10 in Table 1.2).

| Changes | Features and characteristics | Some positive impacts | Some negative impacts |
|---|---|---|---|
| **Implantable technologies** | Devices increasingly connected to the human body, performing various roles: communication, geolocation, health monitoring | Decrease in missing children<br>Better health outcomes<br>Increased autonomy | Surveillance risk<br>Decreased data security<br>Addiction |
| **Digital identity** | Digital presence on a multitude of networks and other online media | Increased transparency<br>Faster interconnection between individuals and groups<br>Faster dissemination of information | More frequent identity theft<br>Online harassment<br>Fake news<br>Confidentiality threatened |
| **Increased vision** | Various objects allow individuals to connect to other objects or the Internet | Improves the ability to perform tasks (including for people with disabilities)<br>Immediate access to information | Deconcentration<br>Addiction<br>Negative immersive experiences |
| **Connected clothing** | Clothing and other accessories (watches, bracelets, etc.) with chips connected to the Internet and to the person | Increased autonomy<br>Self-management of health<br>Personalized clothing | Surveillance risk<br>Security of threatened data |
| **The connected home** | Remote control of lighting, air conditioning, security, household appliances, etc. | Efficiency in the use of resources<br>Access control<br>Increased comfort | Confidentiality and monitoring<br>Exposure to cybercrime |
| **Big Data** | Accumulation of a huge amount of data and increasing possibilities to process it | Increased decision speed<br>Reduction of data processing costs | Confidentiality<br>Problem of trust in the data collected<br>Loss of jobs in data processing |
| **Driverless car** | Cars running without driver intervention | More free time<br>Reduced driving stress (fewer accidents)<br>Improving mobility (especially for the disabled) | Loss of driver jobs<br>Legal structures (traffic, liability, insurance systems) |

| | | | |
|---|---|---|---|
| **Sharing economy** | Sharing of goods and services made possible by mobile applications, geolocation services and digital platforms | Easy access to resources<br>Feedback on public and direct information<br>Increase in human services | Job instability<br>More opportunities for breach of trust |
| **3D printing** | Creation of a material object from a 3D plan | Accelerated product development<br>Democratization of creative and production capacities<br>Reduction of transport needs | Increase in the volume of waste<br>Piracy<br>Quality of the products |
| **Robotics** | Substitution of robots for humans in an increasing number of domestic and manufacturing activities | Rationalization of supply chains<br>Relocation of production activities | Job losses<br>Accountability and responsibility issues |

**Table 1.2.** *Ten profound changes in the Fourth Industrial Revolution (source: excerpts from Schwab, 2017)*

Schwab places great emphasis on digital technologies, hence the title we give to this Fourth Industrial Revolution. But we must also note the importance of engaging in an energy transition (renewable energies, energy-producing buildings and increasing energy storage capacity). Also, without this being a certainty, the prospect of the end of fossil fuel exploitation (coal, oil, etc.) and the advent of "clean energies" (wind, solar, geothermal, tidal energy, etc.) are opening up.

In terms of behavior, both at work and in society, we can also see that in the West, individuals emphasize the values of freedom and autonomy, wishing to free themselves from collective rules and traditional supervision to satisfy their aspirations. In the previous period, the automobile, after having been a symbol of social success, conveyed these values. But today, it appears more like a constraint and a growing number of individuals would like the car to be autonomous, to free ourselves from it. In addition to Google, which has embarked on clean development (Google Car), most car manufacturers have announced that they plan to market the first autonomous car models by 2020.

The digital revolution derives its originality mainly from the fusion of technologies and their interaction in the physical, digital and biological fields, which allows an unprecedented increase in production capacities. A striking illustration of this is the "factory of the future" (or industry 4.0), which corresponds to a new way of organizing the means of production where, thanks to digitization, everything is done in interaction between the customer's needs, the machines connected to each other and the manufacture of products.

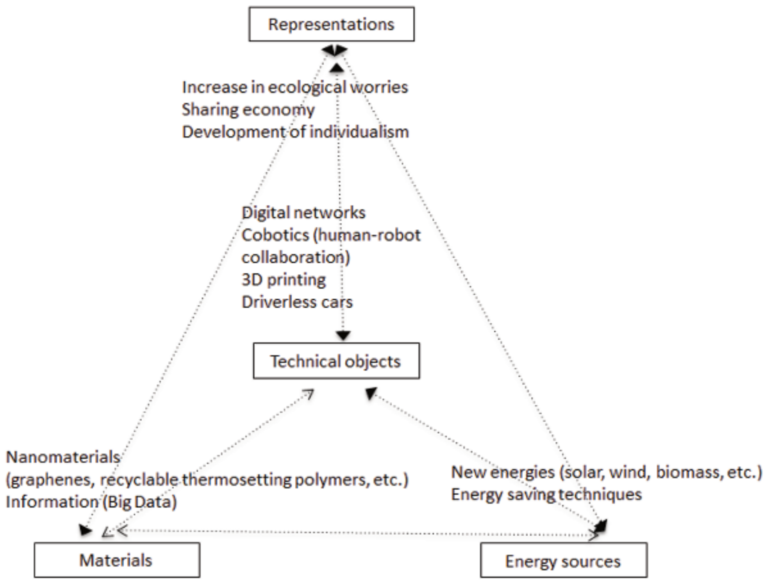


**Figure 1.6.** *Transformation of the socio-technical system to the digital revolution*

To address the contributions of HSS to the understanding of technological change, we proceeded in two steps. The first step allowed us to understand the variety of points of view on the link between technology and social issues. We have focused on the anthropotechnical perspective that we favor because of its ability to overcome all determinism and open up to action. In a second step, we proposed a brief history of technological change to illustrate the intertwining of technical and social factors, recognizing with Robert Cresswell (1996) that it is impossible to separate technical facts from social facts. We will continue by highlighting some of the most significant societal, organizational and individual elements.