

## Technological Advancement and the Transformation of Work and Labor from the First Industrial Revolution to the Age of Artificial Intelligence

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| Article History                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Abstract                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
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| <b>Original Research Article</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <p><i>Technological advancement has played a fundamental role in transforming societies and labor relations throughout history. Since the First Industrial Revolution, the incorporation of machinery, equipment, and new production techniques has reshaped production systems, productivity, occupational structures, and the skills required of workers. Against this background, this study analyzes the impacts of technological advancement on workers and work from the First Industrial Revolution to the contemporary era, focusing on changes in production processes, employment, working conditions, and professional skills. The study adopts a qualitative, exploratory, and descriptive approach based on bibliographic and documentary research, with particular emphasis on studies and reports published by the World Economic Forum. The findings indicate that technological development has an ambivalent character: while it generates productivity gains, reduces production costs, and creates new professional opportunities, it also transforms occupations, intensifies work, and increases the demand for new skills and qualifications. In the context of the Fourth Industrial Revolution, driven by the rapid expansion of Artificial Intelligence (AI), automation, robotics, and the Internet of Things (IoT), these transformations have become increasingly rapid and far-reaching. The study concludes that the effects of technological change are shaped not only by technological factors but also by economic, social, and institutional arrangements. Therefore, addressing these transformations requires coordinated policies aimed at workforce reskilling and upskilling, social protection, and effective regulation.</i></p> <p><b>Keywords:</b> Automation. Mechanization. Technological Evolution. Work. Worker.</p> |
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| <b>Published: 26-09-2026</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <p><b>Copyright</b> © 2026 The Author(s): This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY-NC) which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use provided the original author and source are credited.</p> <p><b>Citation:</b> Valdir Silva da Conceição, Dayana Ferraz Silva, Angela Machado Rocha, Marcelo Santana Silva, Jaqueline Santos Vieira, David Vieira dos Santos, &amp; Giovanna Martins Sampaio. (2026). Technological advancement and the transformation of work and labor from the first industrial revolution to the age of artificial intelligence. UKR Journal of Multidisciplinary Studies, 2(9), 125-138.</p> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

### Introduction

Contemporary society is undergoing constant transformations, with technological advancement standing out as an increasingly pervasive force in organizations and everyday life. In this context, digital technology constitutes one of the main drivers of transformation in the twenty-first century, significantly influencing social, economic, and professional relations [1-5].

Technological development has been driven, among other factors, by the need to optimize processes, reduce reliance on human labor, and increase productivity, thereby creating greater availability of time for other activities, including

leisure. However, this process has also brought negative consequences, such as structural unemployment, environmental degradation, the excessive exploitation of natural resources for the extraction of raw materials, and increased waste generation. At the same time, the adoption of new technologies by organizations has generated benefits such as increased productivity, competitiveness, and profitability, as well as improvements in managerial efficiency and the ability to meet customer needs. Thus, the effects of technology can be observed both within

organizational environments and in the broader social context [6-12].

The influence of technological advancement can also be observed in the development of different fields of knowledge and professional practice, including administration, medicine, engineering, physics, and geography, among others. The use of technological resources has contributed to the improvement of professional methods, processes, and practices, expanding opportunities for development and innovation.

Nowadays, organizations across a wide range of sectors, as well as different production and organizational processes, depend to varying degrees on the use of technological resources to support their development, continuity, and competitiveness. In this context, the ability to keep pace with technological transformations has become an important factor for the survival and growth of organizations in a market characterized by constant change and intense competition [13-19].

In the professional context, technological knowledge also represents a competitive advantage for individuals seeking to enter and remain in the labor market. Proficiency in technological tools and resources, combined with the ability to keep pace with technological developments, can contribute to professional qualification and increased employability. Conversely, the lack or insufficiency of such knowledge may hinder adaptation to new professional requirements and increase the risk of skills obsolescence among workers.

This relationship between technological development and transformations in work is not a recent phenomenon. Since the First Industrial Revolution, profound changes in production processes have reshaped the organization of work, promoted the specialization of activities, and altered the relationships between workers and the means of production. Over time, each new stage of technological development has produced different impacts on work and worker, establishing a complex relationship among innovation, productivity, professional qualification, employment, and working conditions [20-23].

Against this backdrop, it is important to understand how technological advancement has transformed work and Workers from the First Industrial Revolution to the contemporary era. Such an understanding makes it possible to analyze the transformations that have occurred in production processes and labor relations, considering both the benefits provided by technological development and the challenges and impacts arising from its adoption by organizations and society. Accordingly, this study aims to analyze how technological advancement has affected work and workers from the First Industrial Revolution to the

present day, considering its implications for productivity, professional qualification, employment, working conditions, and social relations.

## Methodology

The present study is characterized as a qualitative, exploratory, and descriptive research study, conducted through bibliographic and documentary research. A qualitative approach was adopted due to the need to understand the transformations resulting from technological advancement and their effects on work, workers, and their social relations, taking into account the historical context and the different stages of the industrialization process [24].

Regarding its objectives, the study is exploratory, as it seeks to broaden the understanding of the relationship between technological development, work, and transformations in professional skills, and descriptive, as it presents and systematizes the main characteristics of the Industrial Revolutions and their impacts on production processes and workers.

The bibliographic research was conducted through the consultation of books, scientific articles, academic papers, and other publications related to technological development, the Industrial Revolutions, the organization of work, automation, professional qualification, and the social impacts resulting from the adoption of new technologies. The references consulted include authors who discuss the relationship between technology, work, and capitalism, as well as studies addressing the transformations brought about by industrialization and digitalization.

The documentary research, in turn, included institutional documents and reports related to technological transformations and the professional skills required by the labor market, with particular emphasis on reports published by the World Economic Forum. These documents were used to identify the skills considered relevant during different periods and to analyze their evolution over time, particularly in 2015, 2020, and the projections for 2030.

For the historical analysis, the four stages of the Industrial Revolutions were considered. The First Industrial Revolution was analyzed based on the introduction of the steam engine and the mechanization of production; the Second Industrial Revolution, based on the expansion of electricity, petroleum-based products, and large-scale production; the Third Industrial Revolution, considering the development of microelectronics, information technology, telecommunications, and automation; and the Fourth Industrial Revolution, based on the integration of digital, physical, and biological technologies, with particular

emphasis on Artificial Intelligence (AI), robotics, the Internet of Things (IoT), automation, and big data.

The analysis of the data and information was conducted using an interpretative and comparative approach, seeking to identify continuities, disruptions, and trends in the relationship between technological development and work. Initially, the main technological transformations associated with each historical period were identified. Subsequently, their effects on production processes, employment, working conditions, and the skills required of workers were analyzed. Finally, a comparative analysis of the different stages was conducted to understand how technological advancement has progressively transformed the profile of the worker.

The analysis of professional skills was based on the skills identified in reports published by the World Economic Forum, making it possible to observe changes in professional requirements across different periods. The skills were organized into categories related to cognitive, behavioral, managerial, technological, and adaptive dimensions, enabling the establishment of a relationship between technological transformation and the need for workforce reskilling.

Thus, the methodological approach adopted made it possible to integrate a historical perspective on the Industrial Revolutions with an analysis of contemporary transformations in work, enabling a discussion not only of the gains resulting from technological development but also of the challenges associated with unemployment, job precariousness, professional qualification, inequality, and the need for workers to adapt to new technologies.

### **Historical Evolution Of Work And Technology**

Human development is closely related to the creation of different forms of work and the pursuit of well-being, a process that has evolved and been refined over time. This development can also be observed during the Industrial Revolution, a period marked by the introduction of new technologies and the mechanization of certain activities, with the aim of reducing human intervention in some stages of production processes. These transformations helped reduce the effort required to perform tasks and increase the time available for well-being, leisure, and entertainment, while also bringing about changes in working conditions and contributing to improvements in quality of life [20-23; 25].

Technology is not a new subject, as human beings have sought, since ancient times, to develop techniques aimed at improving their well-being and facilitating their use in production processes, making technology an unavoidable element of the contemporary world. It generates social, economic, psychological, and political changes in the

performance of work, causing disruptions in production systems and transformations in the division of labor [20-23].

The rise of capitalism brought about profound transformations in the relationship between capital and labor, affecting both the work environment and the very nature of work. Before capitalism, labor existed predominantly in its concrete form, that is, as a qualitative activity directly related to the production of objects intended for a specific purpose. For example, a shoemaker produced shoes, while a baker produced bread, so that each activity had a concrete purpose and its outcome served a specific use. Under capitalism, however, the concrete dimension of labor came to coexist with an abstract, quantitative dimension, in which what matters for the valorization of capital is the socially necessary labor time required to produce a commodity. In this way, labor is abstracted from its particular characteristics, making it possible to establish an equivalence between different products, such as a shoe and a chair [26].

In this context, objects that were previously produced predominantly to satisfy a particular use need came to be produced as commodities intended for exchange. Although use value does not disappear, it becomes a necessary condition for a commodity to realize its exchange value. Thus, capitalist production is characterized by a reversal of the logic between producing for use and producing for sale, since commodities are produced primarily for the purpose of being exchanged in the market and contributing to the valorization of capital.

This transformation also profoundly alters social relations of production. In this context, relationships between people come to assume the appearance of relationships between things, constituting the process of reification or commodification of social relations. In this process, workers, deprived of the means of production, are placed in the position of sellers of their labor power, which is purchased by capitalists in exchange for wages. Labor power, therefore, becomes a commodity, and workers are compelled to sell it in order to secure their livelihood. Capitalists, in turn, orient their activities toward the valorization of capital and the pursuit of profit, since labor power has the particular capacity to produce a value greater than that required for its own reproduction. It is precisely this difference between the value produced by workers and the value paid for their labor power that constitutes the source of surplus value and, consequently, the process of capital valorization {26}.

The word technology is derived from the Greek *tékhne*, meaning "craft", "technique", or "art", and *logia*, derived from the Greek *lógos*, meaning "study". Thus, technology can be understood as the study of technical and scientific

knowledge applied to various fields of research. In its earliest form, technology can be exemplified by the discovery of fire, the invention of the wheel, the development of writing, and the creation of instruments and tools [27-29].

Technology consists of a body of knowledge that enables the conception, production, and distribution of goods and services [30]. Among the main technologies applied to production processes are:

- CAD/CAM (Computer Aided Design / Computer Aided Manufacturing): computer-aided design and manufacturing.
- Robots: semi-automatic and automatic actuators that perform predetermined production activities.
- CIM (Computer Integrated Manufacturing): computer-integrated manufacturing.
- CNC (Computer Numerical Control): the use of machine tools controlled by computers.
- FMS (Flexible Manufacturing Systems): Flexible manufacturing systems.
- IT (Information Technology): the use of technological resources for processing, storing, transmitting, and managing information.
- OA (Office Automation): the use of data processing and communication technologies to support the performance of office tasks [31].

### **Technological Advancements And Their Effects**

Technological advancement has eliminated both manual and intellectual jobs and has required workers to develop a new profile based on new areas of specialization, dynamism, versatility, multifunctionality, and the ability to keep pace with technological developments. In addition, it has led to the emergence of new occupations requiring greater intellectual capacity and a high level of qualification. This process has also contributed to the disappearance of certain professions, such as that of the telegraph operator. Functional unemployment, resulting, among other factors, from automation and technological illiteracy, may be associated with the concentration of individuals with low levels of education and limited professional qualifications. Technology also contributes to waste generation and may encourage individuals to pursue power and capital, without, however, eliminating occupational diseases and workplace accidents [21; 23; 31].

It is possible to draw a historical parallel between the First Industrial Revolution and the Third Industrial Revolution, also known as the Digital Revolution, particularly with regard to the impacts of technological innovations on the labor market. In both periods, structural unemployment can be observed, associated with the replacement of certain

human activities by new technologies and the consequent obsolescence of professional skills among specific segments of the working class [21-23; 31].

During the First Industrial Revolution, for example, mechanical looms contributed to replacing the manual dexterity of weavers, intensifying the mechanization of textile production from the nineteenth century onwards. Similarly, during the 1980s, the introduction of robotic arms and the increasing automation of assembly lines in the automotive industry began to replace workers in predominantly repetitive tasks, such as welding, painting, and assembly [22].

These technological transformations triggered significant reactions among workers, expressed through protests, mobilization, and strikes, while also intensifying tensions among workers, trade unions, and employers. In this context, debates over reducing working hours also gained prominence as a mechanism for preserving jobs in the face of automation processes [22].

In contemporary society, this process has taken on new characteristics with the growing use of Artificial Intelligence (AI), which expands the capacity to automate tasks and activities previously performed by human workers. Thus, the adoption of these technologies may contribute to changes in the occupational structure, the reconfiguration of the professional skills required, and, in certain sectors, the displacement of jobs, further intensifying the debate over the impacts of technological innovation on employment [32-34].

An invention can be understood as the discovery or creation of something scientifically or technically new, corresponding to the conception of a new product or process, which may or may not be subject to patent protection. Innovation, on the other hand, refers to the successful commercial application of an invention [31; 35-36].

Technological advancement is not always related to computers or similar technologies, nor does it necessarily represent something unprecedented in the market. It may involve an already established technology that, within a particular organization, is being used for the first time or implemented to replace another form of management, an existing production process, or a product that had previously been used or adopted by the organization [31].

Technologies have impacts on work, people, and companies, which respond differently according to the degree of influence, as well as the benefits and adverse effects resulting from their application in the environments in which they operate [37]. The main impacts in relation to technologies can be observed in Table 1.

**Table 1 – Impacts of Technological on Work and People**

| <b>WORK</b>                          | <b>PEOPLE</b>                              |
|--------------------------------------|--------------------------------------------|
| Content and nature of tasks          | Patterns of communication among people     |
| Skills required                      | Skills required of people to perform tasks |
| Work pressures and pace              | People's ability to exert influence        |
| Interaction among workers            | Levels of personal privacy                 |
| Numbers of workers                   | People's access to information             |
| Distribution and location of workers | Roles performed by people                  |
| Working hours and schedules          |                                            |

*Source: Prepared by the authors based on [37]*

Table 1 provides a broad overview of the effects of technology on the world of work, demonstrating that technological transformations affect not only the tasks performed by workers but also alter how people communicate, exert influence, access information, and perform their roles in organizations.

New technologies produce simultaneous changes across two dimensions: work, by altering the organization and execution of activities, and people, by modifying their relationships, skills, and conditions of participation in the professional environment.

The impacts of technology on work extend beyond the simple replacement of human tasks by machines, also affecting social relations, professional skills, and the conditions under which workers perform their activities. Within the workplace, technological innovations may alter the content and nature of tasks, the skills required, the pace and pressures of work, patterns of interaction among workers, the size and location of the workforce, as well as working hours and schedules. These transformations may result both in the elimination or reduction of certain activities and in the creation of new roles and the demand for new professional skills.

With regard to people, the effects of technology are manifested in patterns of communication, the skills required to perform activities, the ability to exert influence and participate in work processes, levels of privacy, and access to information. Furthermore, the adoption of technologies may alter the roles performed by individuals within organizations, shifting them from predominantly operational activities toward functions related to supervision, analysis, control, and decision-making.

Furthermore, this perspective makes it possible to understand technology as an element that simultaneously transforms the organization of work and workers' experience. Therefore, its effects should not be analyzed

exclusively from the perspective of productivity or automation, but also considering its implications for professional skills, labor relations, autonomy, privacy, and the organization of working hours. This approach is particularly relevant for understanding the contemporary impacts of digitalization and Artificial Intelligence (AI) on the labor market.

The incorporation of technology into people's lives constitutes a genuine challenge, as it involves not only the simple adoption of technologies but also the creation of "dikes", following the metaphor employed by Machiavelli, such as policies to promote mental health, professional reskilling programs, spaces for dialogue, and time for adaptation. In this way, the aim is to prevent "technological floods" from destroying what is most human about work and, instead, to ensure that they help fertilize the ground for new forms of human flourishing [38-40].

This is an anthropological issue, as technology reconfigures the meaning of being human in a world increasingly mediated by machines. However, technology does not transform people in a standardized manner, since its effects depend on individual characteristics and the conditions under which technological integration takes place. In this sense, adapting to technological transformations constitutes a test of resilience and psychological flexibility, whose impacts may be experienced subjectively by each worker.

Among the main reactions of workers to technological transformations are:

Technostress: difficulty or inability to cope with the changes brought about by the use of computers and other technologies in a healthy manner;

Cyberphobia: fear of computers and related technologies [41-44].

The impacts of technology on organizations are presented in Table 2.

**Table 2 – Impacts of Technologies on Organization**

| Focus           | Impact                                                                                                                   |
|-----------------|--------------------------------------------------------------------------------------------------------------------------|
| Individual      | Fears; resistance; adjustment; training/adaptation; performance; occupational health                                     |
| Group           | Group processes; leadership; level of interaction; organization; resistance; performance                                 |
| Organization    | Organization and structure; image; competitiveness; management; performance; product quality and suitability; investment |
| Macroeconomy    | Productivity; production of goods and services                                                                           |
| Consumer Market | Products available                                                                                                       |
| Labor Market    | Employment level; remuneration level                                                                                     |
| Environment     | Contamination; noise; resource exploitation                                                                              |

*Source: Prepared by the authors based on [31]*

Table 2 demonstrates that the impacts resulting from the introduction of new technologies in organizations are not restricted to the production process but encompass different levels, involving individuals, work groups, companies, the economy, the consumer market, the labor market, and the environment.

At the individual level, the adoption of new technologies may trigger different reactions among workers, such as fears, resistance, and the need for adjustment. At the same time, it may require training and professional development processes, directly influencing job performance and occupational health. Thus, the introduction of technologies may represent both an opportunity for professional development and a source of insecurity and a need for adaptation among workers.

At the group level, technology may alter interaction processes among workers, forms of leadership, and the organization of activities. The need to adapt to new tools and working methods may also generate resistance, affecting group performance and the way in which professional relationships are established.

At the organizational level, the effects may be observed in administrative organization and structure, institutional image, competitiveness, and management. Technology may also contribute to improving performance, product quality, and product suitability, in addition to influencing investment-related decisions. Thus, technological adoption may constitute an important instrument for increasing organizational efficiency and competitive capacity.

With regard to macroeconomics, technological advancements may contribute to increased productivity and the expansion of the production of goods and services. However, these transformations may also affect the economic structure and the demand for different types of workers and professional qualifications.

In the consumer market, technology influences the availability of products, enabling the development of new goods and services while modifying production methods and the ways in which consumer needs are addressed.

In the labor market, the impacts can be observed primarily in employment and remuneration levels. Automation and the adoption of new technologies may eliminate certain occupations while simultaneously creating new ones that require different knowledge and qualifications. Therefore, technological advancement may contribute to changes in the occupational structure and increase the need for continuous professional development.

The environmental impacts are also evident, particularly those related to contamination, noise, and the exploitation of natural resources. This demonstrates that the benefits provided by technological development may be accompanied by environmental consequences that need to be considered by organizations and society.

In general, technology produces interdependent and multidimensional impacts. Its effects are not limited to increased productivity or improved organizational processes, as they also affect labor relations, individual behavior, organizational structures, the labor market, consumption, and the environment. Therefore, the adoption of technologies by organizations should consider not only economic and productivity gains but also their social, human, and environmental effects.

“The impact of new technologies, however, is not restricted to individuals and how they react. People form groups of various types and for a wide range of reasons, and these groups also experience the impact of technology and react to it. At the broadest level of aggregation, the company—as the result of the coming together of all the groups that comprise it—also experiences the impact of technology and reacts to it” [31, p. 110].

Technology is fundamental to the survival of organizations, as it reduces costs, increases productivity gains, enhances competitiveness, improves process control, and reduces the need for labor in certain activities that require greater speed in problem-solving. Its use aims to improve effectiveness and efficiency, meet customer needs, and provide a competitive advantage over competitors. Thus, technology constitutes a vital component of organizational survival in the market, given the competition among organizations and the transformations resulting from the rapid pace at which society evolves [20].

This advancement began with the First Industrial Revolution and continues to the present day, accompanying a society that evolves and demands higher quality material goods and increasingly advanced technologies. One of the main pillars of the Industrial Revolution was the replacement of part of human labor by machines, generating significant impacts on production processes and labor relations. Advances also occurred in production methods and techniques, along with changes in society, culture, management, labor relations, and politics [21].

The use of machines, equipment, and techniques to control nature is not a phenomenon originating from the Industrial Revolution, which means that the relationship between human beings and technology is as old as humanity itself. The authors cite three examples to support their argument [23].

The first example is the invention of the wheel, around 3,500 BCE, which is considered one of the most revolutionary inventions in history because it enabled the transportation of loads, facilitated mobility, and contributed to the development of more complex machines, such as gears and mills. This development demonstrates the high degree of abstraction and technical capability achieved by human societies during that period [23].

The second example is the construction of the pyramids in Egypt, around 2,500 BCE, which represents a monumental engineering achievement requiring advanced knowledge of mathematics, physics, astronomy, and logistics. The structures were built using sophisticated techniques for the extraction, transportation, and placement of stone blocks as well as the large-scale organization of labor, demonstrating

that humanity had already achieved a high level of technical knowledge long before the modern era [23].

The third example is the development of Maya society, between approximately 2000 BCE and 900 CE, which possessed advanced knowledge of astronomy, mathematics, and architecture. The Maya developed accurate calendars, a writing system, complex forms of urban planning, and agricultural techniques, such as terrace farming. These elements demonstrate that some civilizations flourished on the basis of technical knowledge and the use of tools and machines, although rudimentary, long before the emergence of industrial Europe [23].

The implications of these observations contribute to dispelling the notion that technology is exclusively linked to capitalism or constitutes a purely modern phenomenon. On the contrary, they demonstrate that technological development has accompanied the trajectory of humanity and can be understood as an inherent condition of the human capacity to create tools, solve problems, and transform the environment in which people live.

### Industrial Revolution

The First Industrial Revolution (1760-1860) emerged with the advent of the steam engine, which began to be used in mineral extraction, the textile industry, and the production of other goods that had previously been manufactured through artisanal and manual methods, replacing part of the physical labor performed by people. This invention was also used to propel vessels, which no longer depended on human power for rowing and instead began to use steam power to navigate rivers and oceans, reducing travel times for the transportation of passengers and goods.

Another important application of the steam engine was in powering railway carriages, replacing animal traction. This also contributed to improving the transportation of people and goods and reducing travel times. During this period, facilities designed to accommodate machinery were constructed, while the amount of work performed within the household decreased [20-21].

The main consequences of the Industrial Revolution are described in Table 3 and presented below:

*Table 3 – Consequences of the First Industrial Revolution*

| BENEFITS                                                                                                     | DRAWBACKS                                                                                                                                                  |
|--------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Acceleration of the pace of production:</b> machines made it possible to produce more goods in less time. | <b>Unemployment:</b> the replacement of workers by machines eliminated certain occupations and increased job insecurity.                                   |
| <b>Lower prices:</b> large-scale production reduced the costs of many products, making them more affordable. | <b>Exploitation of the proletariat and social inequality:</b> many workers received low wages, worked long hours, and faced precarious working conditions. |

|                                                                                                                                                                |                                                                                                                                                                                                                     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Transportation of more goods and people in less time:</b> new technologies, such as railways and steamships, made transportation faster and more efficient. | <b>Pollution:</b> the intensive use of coal and other energy sources increased air, water, and soil pollution.                                                                                                      |
| <b>Rapid economic growth:</b> industrialization increased production, trade, and wealth in industrialized societies.                                           | <b>Rural exodus:</b> many people left rural areas in search of employment in cities, contributing to rapid urban growth.                                                                                            |
| <b>New production techniques:</b> machines, methods, and technologies emerged that transformed the way goods were produced.                                    | <b>Population growth:</b> industrialization contributed to population growth, particularly in cities, although this phenomenon was also associated with improvements in nutrition, medicine, and living conditions. |

*Source: Prepared by the authors based on [20-21; 23]*

Table 3 highlights the contradictory nature of the First Industrial Revolution by simultaneously presenting economic and productive benefits and the social and environmental consequences arising from the industrialization process. Among the main benefits were the acceleration of the pace of production, the reduction in the prices of certain products, the development of transportation systems, economic growth, and the emergence of new production techniques and methods. These factors contributed to increased productivity, the expansion of markets, and the transformation of economic and social structures.

On the other hand, the industrialization process also produced negative consequences. The replacement of certain human activities by machines contributed to the elimination or transformation of jobs, generating insecurity among segments of the working class. At the same time, precarious working conditions, low wages, and long working hours contributed to increasing social inequalities and strengthening labor movements. From an environmental perspective, the intensive use of fossil fuels, particularly coal, led to increasing levels of pollution. Industrialization also stimulated rural-to-urban migration and rapid urban growth, profoundly altering the spatial distribution of populations.

Thus, Table 3 demonstrates that the First Industrial Revolution cannot be understood exclusively in terms of its technological and economic advances. Its effects should be analyzed comprehensively, also considering the consequences for employment, working conditions, social inequalities, the environment, and the organization of societies. This perspective is relevant for understanding the transformations resulting from the Digital Revolution, in which technologies such as automation, robotics, and Artificial Intelligence (AI) similarly have the potential to increase productivity and create new opportunities, but also to transform occupations, require new skills, and intensify certain social risks.

The Second Industrial Revolution (1860-1900) was characterized by the replacement of coal with petroleum

derivatives, the use of electricity to power machines and illuminate cities, which contributed to large-scale electricity Generation, the reduction in communication time between people through the telegraph, and the replacement of certain human activities by machines. Its development extended from 1860 to the First World War [20]. With the introduction of the automobile as a means of transportation, certain occupations, such as carriage drivers and carriage manufacturers, lost importance or were progressively replaced.

The Third Industrial Revolution (1945-?) began after the Second World War, when countries devastated by the conflict required machinery, resources, and labor to support their recovery and development. It represented a productive restructuring and a new configuration of the world order resulting from the transformations that occurred during the postwar period. During this period, the world was divided into two major spheres of influence: on the one hand, the United States of America (USA), which adopted capitalism as its economic model; on the other, the Union of Soviet Socialist Republics (USSR), which adopted socialism as its political and economic model. This division gave rise to a dispute between the two superpowers, a period that became known as the Cold War.

In 2016, during the World Economic Forum held in Davos, the issue of structural unemployment resulting from what is now regarded as the Fourth Industrial Revolution was discussed. This new stage is characterized by technological advancement associated with the Internet of Things (IoT), nanotechnology, and other emerging technologies, in a context in which robotics and automated systems may replace workers, particularly in manual activities. This transformation may increase unemployment among workers with lower levels of specialization and, consequently, encourage the pursuit of new skills, qualifications, and areas of specialization, particularly in technology-related fields. In this context, workers previously engaged in manual activities may transition to roles related to the maintenance, operation, and supervision of machines and automated systems [45].

Table 4 presents some characteristics associated with the different Industrial Revolutions:

**Table 4 – Characteristics of the Industrial Revolutions**

| First Industrial Revolution                    | Second Industrial Revolution                                      | Third Industrial Revolution                                                                                              |
|------------------------------------------------|-------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|
| Increased labor productivity                   | An economy increasingly closed to unskilled workers               | Scientific revolutions: microelectronics, microbiology (genetic engineering), and the energy revolution (nuclear energy) |
| Increased productivity                         | Expansion of intellectual capacities as a requirement             | Service economy: (lean and highly specialized)                                                                           |
| Introduction of scientific reasoning           | Replacement of human labor in production and services by machines | Globalized economy: accelerated by the revolution in information and communication networks                              |
| Humans transformed into appendages of machines |                                                                   |                                                                                                                          |
| Urbanized societies                            |                                                                   |                                                                                                                          |

*Source: Prepared by the authors based on [20-21; 23]*

Table 4 highlights the evolution of the characteristics of the Industrial Revolutions and makes it possible to identify a progressive relationship among technological development, increased productivity, transformation in production processes, and changes in the skills required of workers. During the First Industrial Revolution, the introduction of machines and the mechanization of production increased labor productivity and output, while simultaneously reducing workers' autonomy in response to the pace imposed by machines. This process was associated with the expansion of factory-based activities and the increasing urbanization of societies.

During the Second Industrial Revolution, the more intensive incorporation of science and technology into production processes expanded mechanization and changed the profile of the workforce. The growing use of machines began to restrict certain opportunities for low-skilled workers, while new forms of production required greater development of technical and intellectual capacities. During this period, the replacement of human labor by machines also began to extend to certain service-related activities.

In the Third Industrial Revolution, in turn, the relationship among science, technology, and production became increasingly marked by the development of microelectronics, information technology, telecommunications, biotechnology, and new energy technologies. The economy became progressively more based on services, knowledge, and information, while the expansion of communication technologies fostered globalization and the integration of markets on a global scale.

Thus, Table 4 demonstrates that each Industrial Revolution brought about changes not only in the tools and methods of

production but also in the organization of work and the professional profile required of workers. A trajectory can be observed in which workers moved from predominantly manual activities toward functions requiring increasingly higher levels of technical qualification, cognitive abilities, and adaptation to innovation. In this sense, the Third Industrial Revolution constitutes an important precursor for understanding the current transformations driven by digitalization, automation, and Artificial Intelligence (AI), which increase the need for workforce reskilling and continuous adaptation to technological change.

The Fourth Industrial Revolution is not limited to the introduction of new technologies; it brings about unprecedented changes in terms of speed, breadth, and systemic impact. Innovation is disseminated at an exceptional pace, affecting different disciplines and sectors and transforming economies, jobs, and societies, while also influencing the very conception of what it means to be human. The challenge lies in managing this transition so that its benefits are broadly distributed and its inequalities mitigated. This represents a process of radical integration in which the distinction between the physical, digital, and biological spheres becomes increasingly blurred, giving rise to a new technological, economic, and social paradigm [45-47].

There is a perverse dialectic of technological modernization under capitalism, in which technology destroys jobs on a massive scale, creating a reserve army composed of unemployed and underemployed workers that exerts downward pressure on wages. The jobs that remain are restructured, deregulated, and unprotected, losing their status as "formal employment" and becoming increasingly similar to informal work. The result is a double penalty, in which workers either lose their jobs or, if they retain them, lose rights, dignity, and stability. Technology should

therefore be critically analyzed, as it does not constitute an automatic "blessing" but rather a field of dispute between capital and labor. The contemporary political and social challenge is to build mechanisms - such as legislation, trade unions, public policies, and social oversight of technology - so that innovation contributes to humanizing work rather than making it increasingly precarious [48-56].

Unemployment, particularly in occupations involving manual activities, tends to reduce workers' bargaining power, highlighting one of the contradictory dimensions of capitalist development. In this context, rising unemployment and the existence of a pool of available workers may strengthen employers' bargaining power, contributing to downward pressure on wages and to the reduction or flexibilization of certain social rights. As a consequence, some workers may be subjected to more precarious working conditions, with wages insufficient to ensure adequate levels of social reproduction [48-56].

This dynamic demonstrates that the effects of technological advancement on work are not limited to the replacement or transformation of certain occupations, but may also affect power relations between capital and labor, particularly

when the adoption of new technologies occurs without institutional mechanisms capable of ensuring social protection, professional qualification, and decent working conditions [48-56].

The process of deconstruction of the world of work as it was known in the twentieth century, involves formal employment being in decline and replaced by a multiplicity of precarious contracts that mimic informal employment. Unemployment is no longer temporary but has assumed a structural and technological character, that is, it has become permanent and increasingly widespread. Globalization and technology constitute driving forces behind this process, operating in combination to reduce the value of labor power and weaken workers. The result is an unequal society in which work loses its character as a social right and becomes a temporary privilege, granted under increasingly stringent conditions [48-56].

The skills discussed at the World Economic Forum in Davos were analyzed to identify the main skills required of workers. Projections were presented for the years 2015, 2020, and 2030, as shown in Table 5.

**Table 5 – Key Skills for Workers**

| 2015                         | 2020                         | 2030                                 |
|------------------------------|------------------------------|--------------------------------------|
| Complex problem-solving      | Complex problem-solving      | Resilience, flexibility, and agility |
| Critical thinking            | Critical thinking            | Analytical thinking                  |
| Creativity                   | Creativity                   | Talent management                    |
| People management            | People management            | Environmental management             |
| Coordinating with others     | Coordinating with others     | Creativity                           |
| Emotional intelligence       | Quality control              | Networks and cybersecurity           |
| Judgment and decision-making | Judgment and Decision-making | Networks and cybersecurity           |
| Service orientation          | Service orientation          | AI and big data                      |
| Negotiation                  | Negotiation                  | Leadership and social influence      |
| Cognitive flexibility        | Active listening             | Curiosity and lifelong learning      |

*Source: Prepared by the authors based on the World Economic Forum (2015, 2020, 2025)*

Table 5 presents the temporal evolution of the skills required of workers by capital, with projections for 2015, 2020, and 2030, demonstrating a significant change in the professional profile demanded by the labor market.

In 2015, the skills listed were predominantly cognitive and interpersonal, with a strong emphasis on the ability to solve problems, think critically, and interact with others. The labor market valued human skills that machines had not yet been able to replicate, such as creativity, empathy, judgment, and social interaction. This period was marked

by the strengthening of the discourse surrounding "emotional competencies."

In 2020, most of the skills identified in 2015 remained in demand, but two significant substitutions were observed. Emotional intelligence was replaced by quality control, a more technical and operational skill, reflecting pressure for efficiency and standardization in a context of work intensification and economic crisis. The second change was the replacement of cognitive flexibility with active listening, indicating a greater emphasis on communication and practical empathy in the workplace.

This period, marked by the COVID-19 pandemic and the acceleration of digitalization, highlighted a tension between maintaining human skills and the growing demand for technical and quality-control competencies. The ability to "listen actively" gained prominence as a management tool in a context characterized by remote work and crisis.

For 2030, a more significant shift can be observed in the profile of the skills required. Only three skills identified in both 2015 and 2020 remained: creativity; judgment and decision-making; and leadership and social influence. The projected skills can be grouped into three broad categories: adaptive and behavioral skills, including resilience, flexibility, and agility, as well as curiosity and lifelong learning; managerial and strategic skills, encompassing talent management, environmental management, and leadership and social influence; and technological and security skills, comprising analytical thinking, networks and cybersecurity, as well as AI and big data.

This period projects a worker who needs to be simultaneously technologically literate, particularly in areas such as AI, big data, and cybersecurity, and deeply human, demonstrating resilience, creativity, leadership, and a willingness to engage in continuous learning. Creativity and human decision-making capabilities remain relevant, but they are increasingly complemented by advanced technical skills and greater environmental and social awareness.

The skills listed reflect the needs of globalized capital rather than necessarily the needs of workers or society as a whole. The emphasis is placed on high-level skills, suggesting that the future of work may be restricted to the most highly qualified professionals. None of the skills mentioned encompasses aspects such as collective organization, class consciousness, political participation, or labor rights. This absence suggests a conception in which workers are understood predominantly as individuals who must adapt to transformations in the labor market, rather than as collective subjects endowed with rights and the capacity for organization and collective bargaining.

### Final Considerations

The present study aimed to analyze the impacts of technological advancement on work and workers, from the First Industrial Revolution to the contemporary era, considering the transformations that have occurred in production processes, employment, working conditions, and professional skills. The analysis made it possible to understand that the relationship between technology and work is not a recent phenomenon, but has accompanied the trajectory of the development of human societies, assuming different characteristics according to the historical, economic, and social context.

The analysis of the Industrial Revolutions demonstrates that each stage of technological development brought about significant changes in the organization of production and labor relations. The First Industrial Revolution was marked by mechanization and the use of the steam engine; the Second Industrial Revolution by electrification, petroleum derivatives, and the expansion of industrial production; the Third Industrial Revolution by microelectronics, information technology, telecommunications, and automation; and the Fourth Industrial Revolution is characterized by the increasing integration of digital, physical, and biological technologies, with particular emphasis on Artificial Intelligence (AI), robotics, the Internet of Things, and big data.

The findings demonstrate that technological advancement has an ambivalent character. On the one hand, the incorporation of new technologies makes it possible to increase productivity, reduce costs, improve the efficiency of production processes, enhance products and services, and create new employment opportunities. On the other hand, automation and mechanization may lead to the replacement or transformation of certain occupations, particularly those involving repetitive and standardized tasks. Thus, technological development should not be understood exclusively as a factor of economic progress, but also as an element capable of producing different social effects across groups of workers.

The historical analysis also demonstrates that technological transformations have progressively altered the professional profile required by the labor market. The predominantly manual worker of the early stages of industrialization was gradually replaced or complemented by workers with higher levels of technical qualification, cognitive abilities, and technological proficiency. In contemporary society, this trend has intensified, requiring skills related to problem solving, critical and analytical thinking, creativity, resilience, adaptability, leadership, and proficiency in digital technologies.

In the context of the Fourth Industrial Revolution, the speed of technological transformations further amplifies this challenge. AI, robotics, automation, and other digital technologies have the potential to transform occupational activities, eliminate certain tasks, and create new roles. However, the effects of these transformations are not determined exclusively by technology. They also depend on forms of work organization, corporate strategies, public policies, economic conditions, and the institutions responsible for protecting workers.

In this regard, professional qualification becomes a fundamental element in addressing the transformations currently underway. The need for continuous learning and the development of new skills demonstrates that

technological adaptation cannot be attributed exclusively to workers. Companies, educational institutions, governments, and organizations representing workers also have a responsibility to build mechanisms for training, reskilling, and social protection.

Another aspect identified in the study concerns the need to critically analyze the relationship between technology and work. Although the discourse associated with innovation often emphasizes gains in productivity and competitiveness, it is also necessary to consider issues related to technological unemployment, the precarization of labor relations, inequality, work intensification, and the distribution of the benefits generated by technological development. Technology, therefore, should not be understood as a neutral phenomenon or as an automatic solution to economic and social problems.

It can be concluded that the main contemporary challenge is not to prevent technological advancement, but to create conditions for its incorporation to occur in a socially responsible manner. This requires public policies for professional training and reskilling, social protection mechanisms, regulation of new forms of work, and organizational strategies that reconcile innovation, productivity, and decent working conditions.

Thus, the trajectory analyzed demonstrates that technology and work are not necessarily antagonistic phenomena. Their relationship can generate economic and social gains when guided by mechanisms capable of distributing the benefits of innovation and mitigating its adverse effects. In the context of the Fourth Industrial Revolution, this issue becomes even more relevant, as the speed and breadth of technological transformations require new approaches to preparing workers, organizations, and society as a whole.

Finally, the study demonstrates that the future of work will depend not only on the capacity to develop new technologies, but also on society's ability to determine how, where, and for whom these technologies will be used. In this context, technological development should be associated with the valorization of work, the expansion of opportunities for professional qualification, the reduction of inequalities, and the promotion of working conditions compatible with human dignity.

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