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Artículo Original de Investigación

CMQ Matrix for Occupational Impact Measurement 4.0

Matriz CMQ para la Medición de Impacto Ocupacional 4.0

José Luis López Carmona[1]
orcid.org/0000-0003-4640-7116
joseluis.lopez@trabajo4cero.com

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Abstract

This article presents its own original methodology to measure the occupational impact of the digitalization of companies, or occupational impact 4.0, by measuring 10 indicators obtained in research carried out by the author on the effects of Industry 4.0 on occupations and jobs. Drawing on different research traditions, the matrix of indicators measures the occupational impact, individually in each job, connecting the substantive content of the work (the tasks and activities carried out in the workplace) with the specific organization of work that takes place in each company or industrial plant because of its digital transformation programs.

Keywords: Occupational impact, digitalization.

1 Universidad Complutense de Madrid, Spain. PhD in sociology and anthropology from the Universidad Complutense de Madrid (Spain). His area of research is the transformations of work in the Fourth Industrial Revolution, which is defined as work 4.0. His professional career has been in the business world, developing a career of more than 20 years in Human Resources, and holding management positions and consultant specialized in Selection and Training.

Resumen

En este artículo se presenta una metodología propia y original para medir el impacto ocupacional de la digitalización de las empresas, o impacto ocupacional 4.0, mediante la medición de 10 indicadores obtenidos en una investigación realizada por el autor sobre los efectos de la industria 4.0 en las ocupaciones y empleos. Recogiendo diferentes tradiciones de investigación, la matriz de indicadores mide el impacto ocupacional, de manera individual en cada puesto de trabajo, conectando el contenido sustantivo del trabajo (las tareas y actividades que se realizan en el puesto de trabajo) con la concreta organización del trabajo que se desarrolla en cada empresa o planta industrial como resultado de sus programas de transformación digital.

Palabras clave: Impacto ocupacional, digitalización.

Introduction

In recent years, growing concern about the implications of technological change on the labour market has led social scientists to pay greater attention to changes within occupations and jobs. There is a broad consensus in the literature on how the incorporation of digital technologies that play a leading role in the Fourth Industrial Revolution, together with new configurations of work organization, has several effects on the what we do and the how they are performed the jobs (Acemoglu & Restrepo, 2017; Author, 2015; Brynjolfsson et al., 2018; Fernández-Macías & Bisello, 2020; Frey and Osborne, 2013; Lahera Sánchez, 2019)there is increasing concern about the future of jobs and wages. We analyze the effect of the increase in industrial robot usage between 1990 and 2007 on US local labor markets. Using a model in which robots compete against human labor in the production of different tasks, we show that robots may reduce employment and wages, and that the local labor market effects of robots can be estimated by regressing the change in employment and wages on the exposure to robots in each local labor market—defined from the national penetration of robots into each industry and the local distribution of employment across industries. Using this approach, we estimate large and robust negative effects of robots on employment and wages across commuting zones. We bolster this evidence by showing that the commuting zones most exposed to robots in the post-1990 era do not exhibit any differential trends before 1990. The impact of robots is distinct from the impact of imports from China and Mexico, the decline of routine jobs, offshoring, other types of IT capital, and the total capital stock (in fact, exposure to robots is only weakly correlated with these other variables.

Unlike what happened in previous waves of automation, a term we use to signify the continuous process of technological change that takes place in companies – the creative destruction that schumpeter proposed, this new wave It brings with it major changes in the labour market. whereas in previous technological revolutions, only routine tasks could be automated or could be converted into explicit, codifiable rules (Author, 2015; Author and Dorn, 2013), the new technologies of the Fourth Industrial Revolution they can automatically infer rules from observing corresponding inputs and outputs, so automation can reach many more types of tasks than were feasible in the past (Acemoglu & Restrepo, 2017; Brynjolfsson et al., 2018; Frey and Osborne, 2013)there is increasing concern about the future of jobs and wages. We analyze the effect of the increase in industrial robot usage between 1990 and 2007 on US local labor markets. Using a model in which robots compete against human labor in the production of different tasks, we show that robots may reduce employment and wages, and that the local labor market effects of robots can be estimated by regressing the change in employment and wages on the exposure to robots in each local labor market—defined from the national penetration of robots into each industry and the local distribution of employment across industries. Using this approach, we estimate large and robust negative effects of robots on employment and wages across commuting zones. We bolster this evidence by showing that the commuting zones most exposed to robots in the post-1990 era do not exhibit any differential trends before 1990. The impact of robots is distinct from the impact of imports from China and Mexico, the decline of routine jobs, offshoring, other types of IT capital, and the total capital stock (in fact, exposure to robots is only weakly correlated with these other variables.

The concept used in this research to understand the occupational impact of the current technological revolution is that of task, as a basic unit of work activity that produces real results (Autor, 2013). In this approach, work is considered an input, a factor of production, and tasks are considered discrete units that require specific skills and attitudes to be performed. Different types of tasks require different types of skills, quantitatively and qualitatively: some tasks require simple skills, other tasks require complex skills; Some tasks require very specific skills and some tasks only generic skills (Fernández-Macías & Bisello, 2020). Thus, the incorporation of a new generation of technologies in companies generally tends to eliminate, transform or add specific types of tasks, thus transforming the content of jobs and occupations (Arntz et al., 2016; Frey and Osborne, 2013; Hötte et al., 2022; Nedelkoska & Quintini, 2018).

This approach based on the immediate relationship between technology and work has been criticized for certain aspects of the theory on which it is based (Rodrigues et al., 2021). From this critical perspective, Fernández-Macías and Bisello (2016) have developed a taxonomy of tasks that makes it possible to assess the impact of technology on occupations, explaining not only the what do people do at work? but also the how do they do their job? In this way, your taxonomy proposal classifies tasks according to their content and according to the methods and tools employed. This taxonomy has been used in different works by the authors (Eurofound, 2018; Fernández-Macías et al., 2018; Fernández-Macías & Bisello, 2020)2018; Fern\\uc0\\u225{}ndez-Mac\\uc0\\u237{}as & Bisello, 2020, showing its usefulness in categorizing occupational impact. In our opinion, the model has a primary advantage, which is that it allows the content of the job to be studied individually, allowing the comparison of results between similar jobs in different companies or economic sectors, or making the comparison between different groups or professional strata. In addition, as a second advantage, the model relates the tasks performed in the workplace with the socio-productive reality in which these tasks are performed within a company, since organizational and technical factors such as the autonomy of the worker or the level of routine and standardization of the work performed, among others, are evaluated.

Along the same methodological lines, working with individual data, several studies have been published in recent years with a different proposal for measuring and evaluating occupational impact. In this new approach, it is proposed that the development and evolution of new technologies, such as artificial intelligence, machine learning, or industrial robotics, contribute to the development of certain cognitive skills at work, such as sensorimotor interaction, visual or auditory processing, or attention, among others. Therefore, unlike the classic task approach (represented by David autor, for example) that directly relates the new digital enablers to the change of tasks, it is proposed that the use of artificial intelligence is not only aimed at replacing existing standardized tasks, but also contributes to transforming the way in which these tasks are performed with the use of new cognitive skills. By associating these cognitive skills with the different tasks performed, the occupational impact on each job can be measured (Felten et al., 2018; Fernández-Macías et al., 2018; Green et al., 2022; Hernández-Orallo, 2017; Tolan et al., 2020)2018; Green et\\uc0\\u160{}al., 2022; Hern\\uc0\\u225{}ndez-Orallo, 2017; Tolan et\\uc0\\u160{}al., 2020.

Despite the progress that this latest research represents in the consideration of the interactions between technology, the organization of work and occupational change, our central concern has been to develop an interpretative scheme that assembles this system and that accounts for the set of productive transformations that operate in companies with the incorporation of digital enablers in the production system.

This article proposes a matrix of 10 indicators that serve to measure and evaluate the Occupational Impact 4.0 (IO4.0) and that involves considering the set of productive transformations that occur with the digitalization of companies. By this we mean the A set of effects, whether foreseen or unforeseen, that the implementation of digitalization programs in companies has on working conditions. The construction of the matrix has been part of a larger investigation that has been carried out as part of a doctoral thesis (López Carmona, 2023b) recently read by the author at the Universidad Complutense de Madrid. The validity and reliability of the measuring instrument was also tested by measuring the IO4.0 in a set of 28 workplaces in three companies in the industrial sector[2].

The article is structured in several parts. In the following section, we describe the methodology that was followed in the research to identify the various indicators and put together the proposal for measuring Occupational Impact 4.0. Then, in the third section, each of the 10 items considered in the measurement is presented and justified, as well as the weighting of scores assigned to each case. In the following two sections, the mathematical formula for calculating the IO4.0 is presented (fourth section) and the two features that can be evaluated with the proposed measurement procedure are explained: the intensity and the structure of the occupational impact. We end the article with a section of conclusions.

2 Due to lack of space, the description of the procedure and the results obtained in the validity and reliability analysis of the CMQ matrix are omitted. The interested reader is referred to the reading of the corresponding sections of the doctoral thesis (López Carmona, 2023b).

Methodology[3]

Occupational impact 4.0 (IO4.0) is a multidimensional concept because it refers to a complex set of variables that are affected by the automation and digitalization of manufacturing processes. To measure this, and therefore find the necessary indicators, we have resorted to multiple reference points to locate the exact position of an object in the social space. (Cea D'Ancona, 2001:47-53).

To identify the dimensions and indicators of the CMQ matrix (content, organizational methods and devices, and qualification), a series of steps were followed throughout the research, combining the use of documentary sources with the use of the qualitative interview technique (Corbetta, 2010).

In the first place, with the use of various documentary sources, a previous list of variables that, according to the reviewed literature, appeared in studies and research on the transformations of work due to current technological changes was made. The use of documents for the purposes pursued represented a double advantage. First, these documents contain non-reactive information, which is not affected by the relationship between the researcher and the subjects under investigation. In addition, the reading of these documents made it possible to study the evolution of working conditions in Europe over the last 20 years.

Scientific reports and articles on working conditions in Europe and Spain, published since 2016, were used. The reports come from both international and national agencies. Among the first are the reports and studies of the European Commission, Eurofound and the European Economic and Social Council (ESC). Reports from the CES in Spain were also used, as well as studies promoted by the two largest trade unions in our country, Comisiones Obreras (CCOO) and Unión General de Trabajadores (UGT).

This first list was enriched during the research with 24 interviews with key interlocutors, who were asked about the contents and forms that were taking place in the digitalization of companies in the industrial sector. Among the questions addressed in the interviews was the identification of a series of explanatory factors through which these productive transformations altered or changed the working conditions in the occupations and jobs of the sector, and that constituted a new digital work environment. As a result, a map of occupational effects or impacts of the digitalization of the industrial sector was obtained, which was subjected to contrast in a second round of interviews.

The definitive list of indicators was obtained through 12 interviews with workers in the industrial sector who, through their personal experience, described how the digitalization of their centers was affecting their jobs.

3 For reasons of space, the article only mentions and justifies the techniques used in the research and that have been the basis for building the matrix of indicators. It is aimed at the reader interested in the doctoral thesis (b).

Construction of the CMQ matrix: measuring the Occupational Impact 4.0

The review of the recent literature and the evidence found in the interviews we have conducted with key interlocutors and workers, allowed us to develop a proposal of indicators to categorize the impacts or effects that the digitalization of the industry has on working conditions.

In the construction of the matrix of indicators we have gathered different elements that appear in the literature mentioned in the introduction of this article, while adding new dimensions that develop important aspects not considered -or insufficiently considered- in previous models and that in qualitative research have come up in the interviews. Our approach is based on three elements.

First, we collect individual data from the workers, and we analyze the occupational impact on the workplace (Ix), which allows us to make comparisons between groups of workers[4] as well as to obtain a measurement of the real and immediate situation of the work process carried out in the factories and workshops. For this reason, the unit of analysis was the workplace, which, according to the classic definition of Katz and Khan (1989), is a "point or place in the organizational space" of a company, defined by one or more activities carried out by a single individual. The consideration of the workplace as a subject of occupational impact measurement has several virtues:

- In the first place, its study and analysis allow us to know what workers do (content), and how they do it (the organization of work).
- At the same time, it is possible to identify the characteristics possessed by the person who performs the work, such as the educational level or previous experience that they must have to perform the contents of the position, or what technical or transversal skills they must possess.
- Finally, we can analyze the interactions that the worker maintains with other workers, with the machines and equipment he uses, and with the specific tasks and activities that he or she is assigned to perform according to the productive organization.

Drawing on different research traditions on occupational impact, a second differentiating element of our proposal is that it connects the substantive content of work (the tasks and activities carried out in the workplace) with the specific organization of work that takes place in each company or industrial plant because of its digital transformation programs. Given that the digitalization process (incorporation of new technologies and digital machines into the production process) is always a strategic option for each company (Castillo, 1994), its effects are not the same in all companies and in all sectors, which therefore

4 With our matrix of indicators, we can make different types of comparisons between jobs, according to the analysis needs that each study or research requires. In this way, for example, comparisons can be made, within the same company, on the occupational impact received by different jobs. Another example may be to compare the different incidence of occupational impact within the same job between different companies.

allows us to make comparisons at all levels: between positions, areas or departments within the same plant, between companies in this or different sectors, or between branches of activity, etc.

Finally, as a third element of our proposal, in the measurement of occupational impact, workers must answer an individual questionnaire where they are asked for certain items of information related to the changes experienced in their jobs due to the digitalization of their company.

As a result of the previous steps, our model proposes to measure the occupational impact by considering 10 indicators that refer to three dimensions of the work process that are affected by the digital transformation of the company:

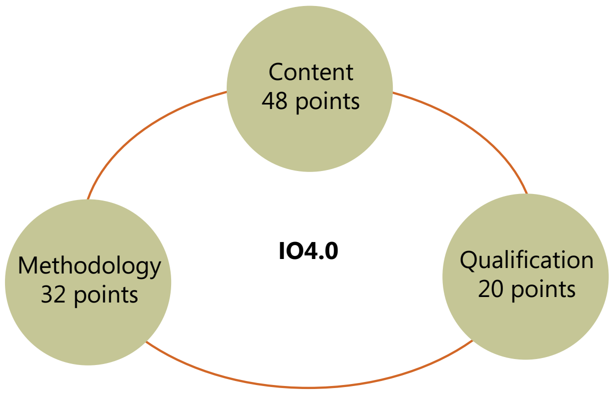
- What does the worker do in his or her workplace? We wonder about the changes in the composition of jobs in terms of the types of tasks that are performed.
- How does it do its job? Being immersed in an organization, the work is carried out with working methods and organizational devices that the company's management uses to direct production within the factory.
- What qualification requirements does the worker need to undertake the tasks? We consider issues such as the level of education needed, what is the value of previous experience or training, or what new knowledge the worker needs to have to perform his or her job.

Once the dimensions and indicators have been identified, which we present below (see table 1), the calculation procedure has been designed. The proposed index measures individually, for each job, the occupational impact in each of the three defined dimensions:

a. The content of the work (C);
b. Organizational methods and arrangements (M); and
c. Qualification requirements (Q).

To be able to make comparisons between groups of workers, we have first assigned the matrix a maximum score of 100 points, which corresponds to the highest degree of occupational impact that a job can suffer because of the digital transformation in the company where it is located. In assigning scores to each of the three dimensions analyzed (see figure 1), the content analysis of the personal interviews carried out with the group of workers in the industry in the previous phases of the research has been taken into consideration. The criterion followed consisted of assigning different weight to each indicator of the matrix according to the greater or lesser importance that the workers themselves gave to each item about which they were asked in the interviews, such as the change in tasks, the greater or lesser intensity of work, the greater or lesser frequency of teleworking, etc. etc.

Figure 1. Dimensions of the CMQ matrix. Distribution of scores



From the answers obtained in the personal interviews, we have obtained some tendencies, on which we have proposed the distribution of the score among the dimensions of Occupational Impact 4.0. In the first place, in all the interviews, the disappearance of some tasks that they previously carried out and the incorporation of new tasks related to the control and supervision of the new machinery introduced in companies because of the digital transformation processes appeared as a fundamental change that the workers had been experiencing. That's why we've assigned the content (C) dimension 48% of the total score.

Second, although there were more heterogeneous situations between occupational groups and jobs, workers pointed to some issues related to the change in work methodologies that accompanied the incorporation of new technologies and machinery. For example, a greater intensity in work, or more frequent changes in the working day throughout the year to undertake changes in production. Also, much more heterogeneous were the situations that occurred with some aspects of the job qualification that appeared in the research. For example, while in some cases of workers saw their autonomy increase and the company became more concerned about their training, in other cases, the opposite trend followed.

Guided by these criteria established from our personal interviews with workers, we have proceeded to distribute the overall score of the index (100 points) among the three dimensions considered, giving greater weight to the dimension that corresponds to the change in the content of the job over the other two.

After assigning a score to each dimension of the score matrix, we have distributed that score among the different indicators that we consider for the measurement of occupational impact 4.0. Table 1 includes a summary table with the dimensions and indicators of the score matrix, which we will detail in the following sections of this chapter.

Table 1. CMQ Matrix for Occupational Impact Measurement 4.0. Dimensions & Indicators

1. Post Content (C)		**48 points**
Physical Tasks	Change in the presence of different tasks in the workplace.	18 points
Intellectual tasks		18 points
Social Tasks		12 points
2. Organizational Methods and Devices (M)		**32 points**
Work intensity	Has there been an increase in demands on the job?	15 points
Job rotation	How often does the worker rotate positions within the factory?	6 points
Atypical working time	How often do there are changes in the working day or work schedule?	6 points
Telecommuting	How often does the worker perform his or her tasks from his or her own home?	5 points
3. Qualification Requirements (Q)		**20 points**
Autonomy	What degree of freedom does the worker have to carry out his tasks without having a supervisor?	10 points
Previous experience	How important is it to have previous experience in other positions, or in other companies, to perform your job?	5 points
On-the-job training	How important is on-the-job training?	5 points

The left column of the table shows the indicators that we have selected for the measurement of occupational impact. In the central column appears the question that is evaluated in each of the indicators, and that helps us to know the occupational change. The questions refer to one of these two issues (Alvira Martín & Aguilar, 2015):

a. The frequency or incidence, measured by the number of times the effect we are measuring appears in a certain agreed time interval; and
b. The magnitude, expressed by the degree of importance that this effect has on the content of the job, the ways of working or the qualification needs of the job.

Finally, in the right column of the table you will see the score we have given to each indicator. Next, we go on to describe and justify the criteria followed in assigning the scores.

Job Content

In this dimension, we consider the job as an activity, as the set of tasks that the worker performs. A task is a "discretely organized unit of work (which can be assigned to one job or another), with a clearly defined beginning and end, performed by an individual to achieve the goals of a job" (Fernández-Ríos, 1995).

We intend to analyze what changes occur in the tasks that make up the workplace with the incorporation of digital enablers in the industrial plant, that is: which tasks disappear or which see their importance decrease? The measurement and quantification of these changes has been carried out on each of the three categories of tasks considered in the Eurofound taxonomy (Fernández-Macías & Bisello, 2016) according to the object on which they act: Physical Tasks; the Intellectual Tasks; and the Social Tasks. The specific tasks we consider in each category are those that, in the light of qualitative research carried out previously, appeared in the conversations and that our interlocutors stated were being affected in one way or another by digitalization in industrial plants.

First of all, we have the Physical Tasks, which operate on things, and encompass the kinds of activities that the literature sometimes refers to as "manual tasks" (Author, 2015). In this category, in addition to considering the tasks that are performed, two related aspects are considered, such as the existence of tiring or painful positions and the repetitive hand and arm movements. Therefore, the items considered in this indicator are:

- Operate, control tools or machines.
- Sorting and packing, packing, or packaging goods and materials
- Driving vehicles, drones or similar.
- Carrying or moving heavy loads with arms.
- Tiring or painful positions.
- Repetitive hand and arm movements.

A second category is made up of intellectual – or cognitive – tasks that operate on ideas or data, and refer to tasks whose task is to process information and solve problems, such as:

- Machine programming.
- Collection and evaluation of information.
- Information processing and reporting.
- Track and inspect machines and/or processes.
- Minor machine maintenance actions.
- Problem solving.

Finally, we consider social tasks as the third category. These are those aimed at interaction with other people, such as:

- Collaboration (digitally or face-to-face) with workers from the same department.
- Collaboration (digitally or face-to-face) with workers from other departments.
- Teach and train (digitally or face-to-face) other workers.
- Manage or coordinate a team.

In assigning scores within the "work content" dimension of IO4.0, we have given equal weight to the listed tasks, distributing the 48 points assigned to the dimension among the 16 tasks (3 points for each of them).

For each category of tasks, we've assigned the score differently. In the case of physical tasks, the preceding research shows that the digitalization of production processes leads to the total or partial disappearance of these tasks in the different professional groups. For this reason, we assign the three points to the total disappearance of this category of tasks, or when these tasks have been reduced, as we consider that in this case there has been an occupational impact as a result of the digitalization of the workplace. On the other hand, when the answer is that these tasks have increased, or have neither increased nor decreased, then we consider that there has been no such occupational impact due to a relatively low digitalization of positions or technical-organizational decisions within companies.

How have the following physical tasks changed in your workplace?	
Totally, it's gone	3 points
It's shrunk, but it hasn't gone away	3 points
It has neither increased nor decreased	0 points
It has increased	0 points

Also based on the evidence collected in the previous research, in the case of intellectual tasks and social tasks, we have given the three points to the answers where these tasks increase in the workplace because of the incorporation of digital enablers in the factory or workshop. On the other hand, we do not assign a score when the task has not changed (it has not decreased or increased), with the understanding that there has been no occupational impact on this aspect of the work content.

How have the following tasks changed in your job?	
It has increased	3 points
It has neither increased nor decreased	0 points
It has decreased	0 points

Organizational Methods and Devices

In this dimension, we consider changes in different aspects related to the way work is organized. By work organization we mean a set of relationships that a worker maintains in his or her workplace with data (information, ideas, theories, various instructions...), with people (co-workers, suppliers, customers, superiors, subordinates, ...) or with things (tools, machines, equipment, raw materials...). These aspects have been revealed to be more contingent and with greater variability between the different companies and between the different positions analysed in the qualitative research. The indicators considered are:

a. Work intensity.
b. Job rotation.
c. Atypical working time.
d. Hybrid work and telecommuting.

With the work intensity we want to measure whether there has been an increase in quantitative and emotional demands in the workplace, or an increase in work rhythms. An increase in these variables is associated, as has been reflected in our research, with a negative impact on occupational health and safety (Eurofound, 2020). We have taken as a reference the definitions used in the European Working Conditions Survey (EWCS). Like this:

- The quantitative requirements of the job refer to the volume of tasks performed in relation to the time available to perform them. In our model we have selected two items from the EWCS: to carry out work at very high speed at least 75% of the working day; and develop the work with tight deadlines also at least 75% of the working time.
- Emotional demands refer to the appearance of disturbing situations for the worker as a result of the interpersonal relationships that must be developed in the performance of their work, such as stress or pressure exerted by a position of authority, for at least 25% of the working day.

Due to the changes brought about by the digitalization of your factory or workshop, have you experienced a change in the intensity of the work you do?	
Yes, there has been an increase in the number of occasions when people work at very high speed (at least 75% of the working day)	5 points
Yes, it has increased the number of times you work with tight deadlines (at least 75% of working time)	5 points
Yes, the emotional demands to carry out the work have increased (at least 25% of the working day)	5 points
No, in fact, the intensity at work has decreased	0 points
No, there has been no increase or decrease in intensity	0 points

For the measurement of the change experienced in the intensity of work, the evidence found is that the three aspects (high speed, work at tight deadlines and emotional demands) are usually linked hand in hand with the technological modernization of factories, where at the same time as the workforce and even the working hours are reduced, an intensification of work is imprinted (Castillo, 1994; Lahera Sánchez, 2005). We have distributed the total score of 15 points assigned to this indicator, giving a score of 5 points to the existence of each situation in the workplace.

Due to the new digital environment in your factory, how often do you rotate from your job?	
Never	0 points
Once a year or more, but not every month	0 points
Once a month or more, but not every week	6 points
Once a week or more, but not daily	6 points
Every day	6 points

The inclusion of job rotation in the model aims to measure how standardization and greater repetitiveness of tasks lead to a greater frequency in which the worker changes from one place to another in the industrial plant, performing tasks of the same level of qualification (polyvalence or multitasking) or developing tasks of higher qualification (task enrichment or multiskilling) to that of your workplace.
The evidence found reveals that this rotation of positions becomes a continuous strategy of flexibilization of the workforce in companies to undertake temporary or seasonal changes in production needs. Therefore, when it is implanted, it is usually accompanied by a certain regularity. That is why we score this indicator (6 points) when the worker states that the rotation is carried out at least with a frequency of "once a month or more, but not every week".

The consideration of the atypical working time the model responds to the need to consider the impact of digitalization on the increase in the frequency of changes in the length of the working day or alterations in working hours to meet changes in demand (incidental increase or decrease) for the goods produced. As the interviews have revealed, these situations have an impact on the safety and health of workers (EU-OSHA, 2018).

In the interviews with key interlocutors, three situations related to the new digital work environment emerged in particular:

- Working more than 10 hours a day.
- Situations where the weekly working day is reduced throughout the year.
- Periods throughout the year when work schedules are changed.

To measure this item, we distributed the 6 points assigned to this indicator among the three situations we considered and scored when the worker states that there has been an increase in their frequency within their job. In such circumstances, we associate, according to the preceding literature, that such circumstances are due to the technical possibility offered by digital technologies applied in production processes, in addition to other technical and organizational considerations that may occur in companies.

On the contrary, we do not assign any score to this item when it is answered that the frequency of such situations has decreased or has not changed (neither increases nor decreases). In such cases, we consider that there is little or no digitalization of production processes, and that they only obey technical and organizational decisions of companies.

Due to the new digital environment in your factory, how has the frequency of the following situations changing...?			
	Increases	**It neither increases nor decreases**	**Decreases**
Working hours of more than 10 hours a day	2 points	0 points	0 points
Reductions in working hours throughout the year	2 points	0 points	0 points
Changes in work schedule throughout the year	2 points	0 points	0 points

The digital transformation of the company allows certain jobs – mainly engineers or technical staff – to develop a part of the weekly working day through hybrid work models and teleworking. In addition, we have seen in the research that this phenomenon, already present previously, has increased with the needs caused by the COVID-19 pandemic that we have experienced in factories.

Due to the new digital environment of your factory, how often do you work from your own home?	
Never	0 points
Once a year or more, but not every month	0 points
Once a month or more, but not every week	5 points
Once a week or more, but not daily	5 points
Every day	5 points

Hybrid work is a new model of employment relationships within companies' hand in hand with technological modernization. Therefore, it is a phenomenon that requires a certain regularity in its application, although its frequency is different depending on the specific characteristics of the job and its position within the organization. For this reason, we consider that there is an occupational impact in this item, and we assign the 5 points, when teleworking occurs with a frequency of at least "once a week or more".

Qualification Requirements

By qualification requirements we mean a set of "manipulation skills and knowledge about the work process, developed by training or experience" that the worker must possess in order to perform his or her tasks (Rigby & Sanchis, 2006).

In measuring the impact in this dimension, we have considered the ways in which this worker acquires these skills within companies, which, as revealed by the evidence found in qualitative research, come from several factors:

a. The worker's ability to perform, without direct supervision, certain tasks or activities in his or her job.
b. The worker's previous experience performing that job or similar positions in the company.
c. The training acquired within the company, closely linked to the position and the forms of work organization that exist.

We have distributed the 20 points assigned to this dimension among the three indicators, assigning them unequal scores. First, we wanted to assess the degree of autonomy that workers possess in the performance of their work. By autonomy we mean the degree of freedom that the worker has to carry out his tasks, and the monitoring and control that is carried out over them, without the need for a supervisor, his organizational capacity to influence the method with which to perform the tasks and the rhythm (speed and intensity) for their performance (Eurofound, 2017). The issues considered for the purpose of measuring the degree of autonomy are:

- Choose or change the order of tasks.
- Choose or change the speed or pace of work.
- Choose or change working methods.
- Determine the tasks, priorities, or goals of the job.

The total score of the indicator (10 points) is distributed among the different options since we consider that technological change favors partial autonomy for issues related to the job. 0 points are awarded when the worker responds that "they need supervision for all tasks".

Which of the following activities can you do without a supervisor?	
Choose or change the order of tasks.	2.5 points
Choose or change the speed or pace of work	2.5 points
Choosing or Changing Work Methods	2.5 points
Determine the tasks, priorities, or goals of the job	2.5 points
I need supervision for all tasks	0 points

In the case of having previous experience in the job, in several interviews carried out the question has come up that the performance of the job itself, or of similar jobs in terms of the tasks carried out over time, became more important in the new work environment, since it allowed the worker to gain knowledge, An expertise, of the specific production process of the factory or workshop that helped him in his professional career. For this reason, we assign the score (5 points) to the two cases in which we have found empirical evidence in the research: when the answer is that experience is "more important than before", or that "it is just as necessary".

In relation to the last 5 years, how important is it to have previous experience to carry out your job?	
Now it's less important	0 points
As before, having previous experience is not essential	0 points
As before, previous experience is necessary to work	5 points
Now it's more important	5 points
I need supervision for all tasks	0 points

Likewise, digital transformation is also associated with a greater consideration of on-the-job training for the correct performance of the job. This item is measured by a scale of 0 to 10, which is scored directly by the worker. We assume the criterion that the worker considers the training as relevant (5 points), when he responds with at least a 7 on the scale.

Calculating the Occupational Impact of Industry 4.0

In each job analysed, we first assign the scores to each of the 10 indicators, following the procedure we have just explained.

Once the score for each indicator has been obtained, we calculate an occupational impact index for each of the three dimensions of the CMQ matrix, adding the scores obtained in the different indicators that compose them. Thus, the impact of Industry 4.0 on the content of a workstation (IOC) will be:

$$IOC_{lx} = c_1 + c_2 + c_3$$

Being:

c_1 = Score obtained in the measurement of the change in the composition of physical tasks.
c_2 = Score obtained in the measurement of change in the composition of intellectual tasks.
c_3 = Score obtained in the measurement of change in the composition of social tasks.

In the same way, we obtain the occupational impact on the occupational environment.

$$IOM_{lx} = m_1 + m_2 + m_3 + m_4$$

Being:

m_1 = Score obtained in the measurement of work intensity.
m_2 = Score obtained in the measurement of job turnover.
m_3 = Score obtained in the measurement of atypical working time.
m_4 = Score obtained in the measurement of teleworking.

Finally, we calculate the occupational impact on the qualification requirements (IOQ) of the job, understood as the ways and contents in which the knowledge and skills required for the performance of the job are acquired:

$$IOQ_{lx} = q_1 + q_2 + q_3$$

Being:

q_1 = Score obtained in the range measurement.
q_2 = Score obtained in the measurement of the previous experience required for the performance of the position.
q_3 = Score obtained in the measurement of the training received in the workplace.

Once the partial indices have been calculated, we calculate the overall index. The Occupational Impact of Industry 4.0 on a job under consideration (IO4.0lx) is calculated simply by arithmetic summation of the scores obtained in each dimension:

$$IO4.0_{(lx)} = IOC_{lx} + IOM_{lx} + IOQ_{lx}$$

Occupational Impact 4.0: evaluation Criteria

The calculation of IO4.0 in workplaces allows us to measure and quantify two different aspects of the occupational impact that derives from the digital transformation of companies: the intensity of the impact and its structure.

In the first place, by intensity of the impact we mean the overall magnitude of the impact on the content, on the methods and organization of the work, and on the qualification requirements of the job we are considering.

The occupational impact on a given job can be the result of different socio-technical situations that occur in the context of the digital transformation of companies. For this reason, along with the intensity, we must evaluate the structure of the occupational impact. In what way the conditions of the job change and are altered in terms of its content, the organization of its work or the qualification requirements that its performance entails.

Intensity of occupational impact

We measure the intensity of the occupational impact by the score obtained in the IO4.0 which, as we have established, brings together and summaries the multiple specific impacts that the job suffers as a result of the digital transformation of the company in which it is registered.

Given that IO4.0 consists of its own original concept, we do not have previous sources or data that allow us to develop a categorization of jobs according to the intensity of occupational impact through a segmentation of cases based on statistical criteria. This may be carried out in further investigations that take into consideration enough cases and measure IO4.0 with the procedures set out here.

In the absence of statistical criteria that future research can provide, we have resorted to subjective criteria to categorize the cases according to the intensity of the occupational impact. In this way, we consider that an IO4.0 score is high when it reaches 70 points, since we understand that in this case the job is affected globally in the different aspects that we are considering: the content of the tasks and activities, the organizational methods and devices of work or the qualification requirements. In the same way, we consider that a job will have a low occupational impact when the IO4.0 score is less than 40 points, this situation corresponding to jobs that are affected in a partial and limited way by specific changes, either to the tasks or to some aspect of the work methods or qualification. Finally, we classify the occupational impact as medium to situations that are not in either of the two previous cases, and that have an IO4.0 score between 40 and 69 points.

Occupational impact	IO4.0 Score
High	70 - 100 points
Middle	40 - 69 points
Low	0 - 39 points

Structure of Occupational Impact

The same occupational impact 4.0 (IO4.0) score, its intensity, may be due to the impact of different combinations of the indicators that make up the IO4.0. For this reason, in addition to the intensity, we must evaluate the structure of the occupational impact, or internal composition, categorizing the jobs according to the highest or lowest score in the partial indices: IOC (Job Content), IOM (Organizational Methods and Devices) and IOQ (Qualification Requirements).

As a preliminary step to compare the jobs, [5] the scores of each partial index had to be normalized, obtaining the corresponding occupational impact coefficients. Thus, we divide the score obtained in each of the indices by the maximum score that can be achieved in each of them (see figure 1):

- The occupational impact on job content (IOC), among 48.
- Occupational impact on organizational methods and devices (IOM), among 32.
- The occupational impact on qualification requirements (IOQ), between 20.

Once the coefficient has been obtained, we estimate that there is an occupational impact in the dimension considered, when the coefficient reaches 0.50; That is: the score obtained is at least 50% of the total score we have given to that dimension.

Types of Industry 4.0 Occupational Impact

The different combination of the coefficients between the three dimensions of Occupational Impact 4.0 (IO4.0) makes it possible to distinguish four types of cases that can occur according to the characteristics of the digital environment in which each job is performed. The diverse reality in which the digital

5 With standardization, we establish a norm an appropriate statistic by which two quantities are transformed for comparison. Among the standardization procedures “the proportions, percentages, ratios, rates and indices stand out” (Sierra Bravo, 1993:479-480).

transformation of companies takes place means that, within the same factory, there can be a more or less developed digital work environment in different production lines, or in different areas or departments of the factory.

In contrast to what happened with the classification of jobs based on intensity, the evidence found in the two series of qualitative interviews that have been carried out provides the basis for the following typology (Table 2), which we describe below.

In the first group of cases (Type I), the occupational impact occurs in work environments where digitalization is scarce and is especially aimed at the automation of machines. It is a work environment that has seen little change from the previous situation and is representative of many manufacturing operator positions. In the interviews, we have learned about several cases of workers in a vehicle cover factory, in a workshop where they manufacture graphics cards, or even a worker who operates an automatic fabric cutting machine.

The intensity of the occupational impact is low (less than 40 points in the IO4.0) and the occupational impact coefficients in the three dimensions are below 0.50, although there may be cases where the coefficient referring to the impact on qualification requirements is higher (IOQ). [6] This is the case of a production manager in an office furniture factory, who must assume demands for greater education and training in very specific areas related, for example, to data management (business analytics), or decision-making, among others because of the introduction of the digitalization of some internal processes in the factory.

Table 2. Typology of occupational impact (IO4.0).

GUY	IO4.0	IOC	IOM	IOQ
I – Emerging Digital Environment	< 40 points	●		●
II – Digital Environment in Transition (A)	40 - 69 points			●
III - Digital Environment in Transition (B)	40 - 69 points		●	●
IV- Mature digital environment	≥ 70 points	●	●	●

Note. The IOC, IOM, and IOQ columns refer to the occupational impact coefficients.
The circles represent that the respective coefficients reach 0.50.

The occupational impact of a second type of case (Type II) occurs in work environments where a more complete digitalization of jobs is beginning to take place than in the previous case. Machine automation is accompanied by better data management, including the introduction of digital devices at the workplace.

6 One or the other situation occurs in companies where digital transformation is in its infancy and is aimed at specific areas or processes. For this reason, we group both into the same type of occupational impact.

The intensity of occupational impact is medium (the IO4.0 is between 40 – 69 points), with higher coefficients of impact on content (IOC) and qualification requirements (IOQ). It is the most common and generalizable situation that can affect any professional group, although it occurs to a greater extent in direct jobs, such as factory operators, who see the content of the tasks they perform altered and at the same time the need for training in topics related to the automation and digitalization of processes or data management increases. In the interviews, we have learned about the case of a worker who operates automatic machines for making sliced bread.

The working environment that occurs in the cases of occupational impact of the next group (Type III) is like that of the cases of the previous type: the automation of machines is accompanied by a digitalization of workplaces and a greater concern for data management.

The intensity of occupational impact is medium (the IO4.0 is between 40 – 69 points), but unlike the previous group, there is a higher coefficient of impact on organizational methods and devices (IOM), due to the fact that some management and coordination, engineering and technical staff positions have seen their autonomy increase, or those who have had a hybrid work model implemented in their companies (with a greater frequency of teleworking). Here, too, these changes are combined with changes in qualification requirements (IOQs), especially the increased importance of possessing a certain academic qualification and previous experience in the job or similar positions.

In the interviews, we have learned about the cases of a director of an industrial paper manufacturing plant who, with the automation and digitalization of processes - together with a reduction in staff in recent years - has had to assume management and analysis functions in recent years that previously fell to other technical profiles. As a result, their qualification requirements have also changed, with new training needs in topics such as decision-making based on data analysis.

The last group of occupational impact cases (Type IV) occurs in digital environments that we can define as mature, where the automation and digitalization of positions is almost total. It occurs in companies and activities whose digital transformation reaches all places and areas of the factory.

The intensity of the occupational impact is high (more than 70 points in the IO4.0) and the occupational impact coefficients in the three dimensions are above 0.60.

In the interviews, we learned about two cases in the engineering area related to the design of technological products and services for customers. We have also heard the case of a technician who oversees the digitalization of the vehicle cover manufacturing plant, and who has had to assume new responsibilities and new training requirements on topics related to industry 4.0, data management and analysis, or decision-making. Finally, we have learned about the case of another technician who supports a plant from his teleworking position in another province where the plant is located; the worker himself assumes that these remote functions could not be carried out without adequate training and previous experience in the position to guarantee the correct performance of his duties.

Graphical representation of Occupational Impact 4.0

An auxiliary tool that allows us to visualize the differences between the different types of occupational impact is the use of radar charts (also known as web, star, or spider charts). The radar chart plots the scores of three or more quantitative variables are plotted on a plane. Each data point is plotted on an individual axis, or radius, starting from the center of the diagram. Low scores are in the center of the radar and high values are in the periphery. Once the data has been plotted on each radius, it is connected to each other through a series of straight lines to create a polygon, which has the same number of sides as the number of variables we are representing.

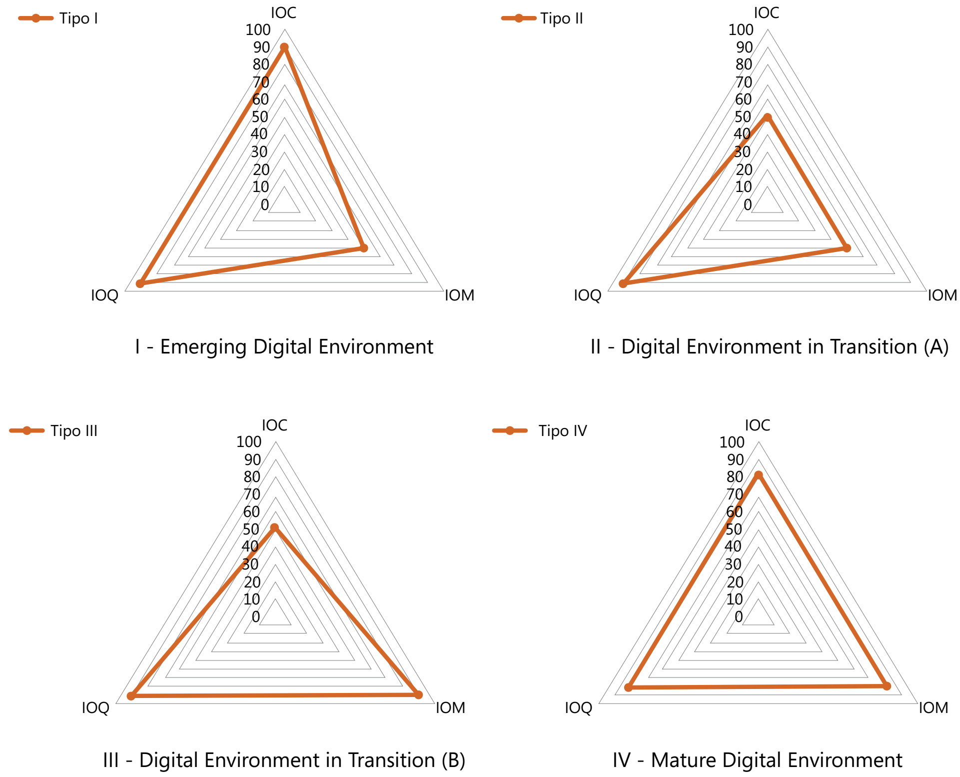
For our purposes, we use the radar chart to graphically represent the scores (occupational impact coefficients that we have previously calculated) of the three dimensions of the IO4.0. The connection of the data points in the graph results in a triangle, which varies in size and shape according to the quantitative relationship between the scores of the three dimensions of IO4.0. Thus, figure 2 represents the four types of occupational impact that we have just described in the previous pages. We see how the area of the triangle, and the shape to which it gives rise, change when moving from one type of occupational impact to another because of the greater or lesser incidence of each dimension of the IO4.0 in each case.

Conclusions

In this article, we have given an account of our own and original methodology that has been developed to measure the occupational impact caused by the digitalization of the industry. This framework of analysis has been the result of a five-year investigation in which the author of the article has studied the effects of the digitalization of the spanish manufacturing sector on working conditions.

The approach from which the matrix of indicators has been developed, and the consequent measurement and evaluation methodology, presents three points of rupture -or innovation- with respect to other models. On the one hand, it considers the set of productive transformations that occur in companies with the incorporation of digital technologies, and not only the direct effects of these technologies on jobs. In addition, there is a second breaking point, which is a continuation of the previous one. Beyond the automation of machines, or the use of artificial intelligence or the new generation of industrial robots, the occupational impact is due to more contextual factors and has a broader, multidimensional character that sometimes the literature on the subject does not consider. Finally, the proposed model or analytical framework allows two interrelated aspects of occupational impact to be measured and evaluated. On the one hand, its intensity, its global effect, which summaries and quantifies with an index the set of effects caused in employment or occupation. But, in addition, through the measurement of each of the 10 indicators that make up the index, it also makes it possible to analyze the structure of the occupational impact in each position, evaluating in each case which specific aspects of the job are affected.

Figure 2. Typology of occupational impact (IO4.0). Radar Chart.



References

Acemoglu, D., y Restrepo, P. (2017). Robots and Jobs: Evidence from US Labor Markets. Working Paper 2017,23285. National Bureau of Economic Research, Cambridge, Massachusetts.

Agencia Europea para la Seguridad y la Salud en el Trabajo [EU-OSHA]. (2018). Estudio prospectivo sobre los riesgos nuevos y emergentes para la seguridad y salud en el trabajo asociados a la digitalización. Oficina de Publicaciones de la Unión Europea, Luxemburgo.

Alvira Martín, F. R., y Aguilar, M. J. (2015). La evaluación de intervenciones sociales: Proyectos, programas y políticas. En M. García Ferrando, F. Alvira Martín, L. E. Alonso, y M. Escobar (Eds.), El análisis de la realidad social: Métodos y técnicas de investigación. Alianza Editorial, Madrid, 270-294.

Arntz, M., Gregory, T., y Zierahn, U. (2016). The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis. OECD Social, Employment and Migration Working Papers 2016,189, OECD Publishing.

Autor, D. H. (2015). Why Are There Still So Many Jobs? The History and Future of Workplace Automation. Journal of Economic Perspectives, 29(3), 3-30. https://doi.org/10.1257/jep.29.3.3

Autor, D. H., y Dorn, D. (2013). The Growth of Low-Skill Service Jobs and the Polarization of the US Labor Market. American Economic Review, 103(5), 1553-1597. https://doi.org/10.1257/aer.103.5.1553

Brynjolfsson, E., Mitchell, T., y Rock, D. (2018). What Can Machines Learn, and What Does It Mean for Occupations and the Economy? AEA Papers and Proceedings, 108, 43-47. https://doi.org/10.1257/pandp.20181019

Castillo, J. J. (1994). El trabajo del sociólogo. Universidad Complutense, Madrid.

Castillo, J. J., y Prieto, C. (1983). Condiciones de trabajo: Hacia un enfoque renovador de la sociología del trabajo. Centro de Investigaciones Sociológicas (CIS), Madrid.

Cea D'Ancona, M. Á. (2001). Metodología cuantitativa: Estrategias y técnicas de investigación social. Síntesis, Madrid.

Corbetta, P. (2010). Metodología y Técnicas de Investigación Social. McGraw Hill, México.

Eurofound. (2017). Sixth European Working Conditions Survey – Overview report (2017 update). Oficina de Publicaciones de la Unión Europea, Luxemburgo.

Eurofound. (2018). New tasks in old jobs: Drivers of change and implications for job quality. Oficina de Publicaciones de la Unión Europea, Bruselas.

Eurofound. (2020). Game-changing technologies: Transforming production and employment in Europe. Oficina de Publicaciones de la Unión Europea, Bruselas.

Felten, E. W., Raj, M., y Seamans, R. (2018). A Method to Link Advances in Artificial Intelligence to Occupational Abilities. AEA Papers and Proceedings, 108, 54-57. 10.1257/pandp.20181021

Fernández-Macías, E., y Bisello, M. (2020). A Taxonomy of Tasks for Assessing the Impact of New Technologies on Work JRC 2020,120618. Comisión Europea, Bruselas.

Fernández-Macías, E., y Bisello, M. (2016). A framework for measuring tasks across occupations. VoxEU.org.

Fernández-Macías, E., Gómez, E., Hernández-Orallo, J., Loe, B. S., Martens, B., Martínez-Plumed, F., y Tolan, S. (2018). A multidisciplinary task-based perspective for evaluating the impact of AI autonomy and generality on the future of work. http://arxiv.org/abs/1807.02416

Fernández-Ríos, M. (1995). Análisis y descripción de puestos de trabajo. Díaz de Santos, Madrid.

Frey, C. B., y Osborne, M. A. (2013). The future of employment: How susceptible are jobs to computerisation? Technological Forecasting and Social Change, 114, 254-280. https://doi.org/10.1016/j.techfore.2016.08.019

Green, F., Felstead, A., Galle, D., y Henseke, G. (2022). Working Still Harder. ILR Journal, 75(2), 458-487. https://doi.org/10.1177/0019793920977850

Hernández-Orallo, J. (2017). The measure of all minds: Evaluating natural and artificial intelligence Cambridge University Press.

Hötte, K., Somers, M., y Theodorakopoulos, A. (2022). Technology and jobs: A systematic literature review. Technological Forecasting and Social Change, 194, 122750. https://doi.org/10.1016/j.techfore.2023.122750

Lahera Sánchez, A. (2005). Enriquecer el Factor Humano: Vol. VI. Fundación de Investigaciones Marxistas, Madrid.

Lahera Sánchez, A. (2019). Digitalización, robotización, trabajo y vida: Cartografías, debates y prácticas. Cuadernos de Relaciones Laborales, 37(2), 249-273. https://doi.org/10.5209/crla.66037

López Carmona, J. L. (2022). La transformación digital de la empresa como marco analítico para el estudio del impacto ocupacional. XIV Congreso Español de Sociología Desigualdades, fronteras y resiliencia. Sociología para crisis globales, 42. https://congreso2022.fes-sociologia.com/wp-content/uploads/2022/07/Libro-de-Actas_final_web.pdf

López Carmona, J. L. (2023a). Más allá de la automatización. Impacto de la Cuarta Revolución Industrial sobre las condiciones de trabajo y la cualificación. Sociología del Trabajo, 103, 29-42. https://doi.org/10.5209/stra.92439

López Carmona, J. L. (2023b). Trabajar en la Industria 4.0. Medición del impacto ocupacional como consecuencia de la transformación digital de las empresas en el sector manufacturero español. Universidad Complutense de Madrid.

López Carmona, J. L. (2024). Medición y evaluación del impacto ocupacional 4.0: Un ejemplo en el sector de alimentación. Lan Harremanak - Revista de Relaciones Laborales. In press. https://doi.org/10.1387/lan-harremanak.26027

Nedelkoska, L., y Quintini, G. (2018). Automation, skills use and training. OECD Social, Employment and Migration Working Papers 2016,189, OECD Publishing.

Rigby, M., y Sanchis, E. (2006). El concepto de cualificación y su construcción social. Revista Europea de Formación Profesional, 37(3), 24-35.

Rodrigues, M., Fernández-Macías, E., y Sostero, M. (2021). A unified conceptual framework of tasks, skills and competences. JRC Working Papers Series on Labour, education and Technology 2021/02). EU Science Hub, Sevilla.

Sierra Bravo, R. (1993). Técnicas de investigación social. Teoría y ejercicios. Paraninfo, Madrid.

Tolan, S., Pesole, A., Martínez-Plumed, F., Fernández-Macías, E., Hernandez-Orallo, J., y Gomez Gutierrez, E. (2020). "Measuring the Occupational Impact of AI: Tasks, Cognitive Abilities and AI Benchmarks". JRC Working Papers 2020/119845). Comisión Europea, Bruselas.