Project

ALMA-AI: Exploring OSH Impact of Algorithmic Management & AI

https://doi.org/10.23775/20250616

Algorithmic management and AI-based systems as a new form of work organisation

Psychosocial factors and implications for Occupational Safety and Health

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JOINT SCIENTIFIC REPORT

Project Leader:

- Jorge Martín (INSST, Spain) (Ed.)

Project Participants:

- Marie Jelenko & Thomas Strobach (AUVA, Austria)
- Joanna Kamińska, Karolina Pawłowska & Katarzyna Hildt (CIOP-PIB, Poland)
- Heidi Lahti & Teppo Valtonen (FIOH, Finland)
- Giuliana Buresti & Fabio Boccuni (INAIL, Italy)
- Benjamin Paty & Virginie Govaere (INRS, France)
- Jon Zubizarreta, Paula Lara & Denis Losada (INSST, Spain)
- Therese Dalsbø (STAMI, Norway)
- Elsbeth de Korte & Mairi Bowdler (TNO, The Netherlands)

Project advisers:

Representatives from the European Agency for Safety and Health at Work (EU-OSHA) and the EU Commission's Joint Research Centre were observer partners:

- Maurizio Curtarelli & Emmanuelle Brun (EU-OSHA)
- Enrique Fernández-Macías & Ignacio González (Joint Research Centre, JRC)

ALMA-AI project

PEROSH

June 2025

ABSTRACT

This joint scientific report presents the Algorithmic Management and AI-based systems (ALMA-AI) project results. Launched within the Partnership for European Research in Occupational Safety and Health (PEROSH), the project focused on the Occupational Safety and Health (OSH) implications of using complex digital technologies for worker management.

The introductory chapter describes the comprehensive literature review methodology, but also the scientific and practical relevance of the topic, as well as the background and objective of the ALMA-AI project, a collaborative effort that involved 18 researchers from eight national OSH institutes, alongside four experts from EU institutions as project advisers.

The subsequent chapter explains the project's theoretical approach, covering both the conceptualisation of 'Algorithmic Management' (ALMA) and the psychosocial factors approach used to understand this emerging trend in the world of work. To this end, several assumptions and definitions from well-known theoretical models on psychosocial risks (Demand-Control-Support, Effort-Reward-Imbalance, and especially Job Demands-Resources) have been explained to delve into OSH implications, particularly focusing on the negative consequences of stress or burnout, as well as its potential positive outcomes, such as engagement or well-being.

Thereafter, the chapter on OSH implications and concerns presents previous relevant findings from cutting-edge institutions on the topic (EU-OSHA, JRC, ILO, OECD), highlighting the increasing prevalence of ALMA, but also outlining the main risks sources identified in the literature, such as those psychosocial by definition (intensification of work, restriction of worker autonomy or social isolation) as well as other related to the use of great amount of data (dehumanisation and datafication, technical malfunctions, or discrimination and privacy as fundamental rights issues).

The final chapters are dedicated to presenting results, main conclusions and a discussion on new evidence from 2022 to 2024 (total of 39 selected scientific papers and reports) concerning OSH implications of ALMA. Specifically, it is emphasized that psychosocial pressures (excessive workload and time-lined efforts) are propelled by this new form of work organisation, as algorithms or AI are applied for worker management today, but also the constraints of workers' resources are underlined (control and decrease of social interactions). This OSH impairment, in which job demands surpass workers´ resources, intensifies psychosocial risks (stress, burnout, violence or harassment) as well as health issues (anxiety, depression, fatigue or accidents).

TABLE OF CONTENTS:

INTRODUCTION

Jorge Martín (INSST, Spain), Fabio Boccuni (INAIL, Italy) & Therese Dalsbø (STAMI, Norway)

1.1. Background and objective of the ALMA-AI project

There is an increasing concern about how Artificial Intelligence (AI) could impact different areas of our society. One of the most pressing issues in the debate in the world of work has been the potential of AI to lead to a massive loss of jobs. However, while some fear this step forward in automation, others highlight that AI would substitute only some tasks, not entire occupations, and it could potentially improve the prevention of risks at the workplace, for example, through smart digital systems that incorporate this advanced technology.

Nevertheless, although the automation of tasks can also leave time for more engaging tasks or personal life, on the other hand, AI can limit workers´ autonomy or freedom and intensify the pace and demands in their work, specifically through algorithmic management applications (its use for coordination, supervision, and evaluation of the workforce). Therefore, AI can boost a new form of work organisation with important psychosocial and OSH implications, being necessary to consider them, especially in a context in which AI for worker management is yet an emergent trend, and enterprises can still identify its risks and implement measures to avoid them from the very beginning, in the design of these complex systems.

Therefore, AI as a general-purpose technology and algorithmic management as an application of digital devices and software to organise work or manage workers have emerged both as scientific topics in the past few years. As an example of this rising scientific relevance, a quick search of review articles in Web of Science (WoS) at the end of May 2025, highlights that using at least one of the terms of “Algorithmic Management” OR “Artificial Intelligence”, reached a total of 41,500 review articles, being striking that more than half of them were published since 2023. Therefore, it seems a need to delve into this emerging scientific literature. Additionally, however, it is important to highlight that when the initial search of both concepts is related to the topic of "Occupational Health and Safety", barely 42 review articles are shown in the list in WoS, underscoring that rather a large number of publications on this particular field of knowledge, it is necessary to pay attention to the OSH implications of algorithmic management or AI for worker management.

Besides the scientific interest itself and its societal relevance, there is an important practical issue for boosting the ALMA-AI project in PEROSH: the forthcoming regulation in Europe. One crucial legislative initiative is the **EU Artificial Intelligence Act** (or AI Act). From an OSH point of view, this law could have an impact because it will be considered **High-Risk AI System** (article 6) all that are intended to be used as a safety component of a product, but also those mentioned in *Annex III*, which includes AI used in employment, **workers management** and access to self-employment that are applied «to allocate tasks based on individual behaviour or personal traits or characteristics or to monitor and evaluate the performance and behaviour of persons in such [work-related] relationships» (Annex III.4.b). To remark on the importance of OSH in this regulation, the AI Act only excludes from the cited High-Risk classification all AI that «does not pose a significant risk of harm to the health, safety or fundamental rights of natural persons» (article 6.3). This legal provision, which regulates as High-Risk AI Systems those applied for specific algorithmic management uses will be enter into force on the 2nd of august 2026, date in which also **all enterprise that uses this AI-systems** (the so-called "deployers") will need to accomplish different obligations, such as the following (article 26):

- «shall take appropriate **technical and organisational measures** to ensure they use such systems in accordance with the instructions for use accompanying the systems (...);
- shall assign **human oversight** to natural persons who have the **necessary competence, training and authority**, as well as the necessary support (...);
- to the extent the deployer exercises **control over the input data** (...) shall ensure (...) is relevant and sufficiently representative in view of the intended purpose of the high-risk AI system;
- shall **monitor the operation of the high-risk AI system** on the basis of the instructions for use and, where relevant, inform providers [... for example, if] AI system presenting a risk [...inform also] the relevant market surveillance authority, and shall suspend the use of that system;
- shall **keep the logs** automatically generated by that high-risk AI system (...) for a period appropriate to the intended purpose (...) of at least 6 months (...);
- before putting into service or using a high-risk AI system at the workplace, deployers who are employers **shall inform workers' representatives and the affected workers** that they will be subject to the use of the high-risk AI system».

Additionally, despite the obligation of develop a risk management system it seems mainly in charge of providers (the developers of the AI-system), another important provision of the AI Act, in this case for the deployers (or enterprise that uses AI) - and which makes sense to the ALMA-AI project purpose – is the obligation of a **fundamental rights impact assessment** (which would include the right for a safety and health workers protection for the High-Risk AI System, such as those used algorithmic management to allocate task, monitor or evaluate workers). As the AI Act establishes (article 27), «deployers shall perform an assessment consisting of:

(a) a description of the deployer's processes in which the high-risk AI system will be used in line with its intended purpose;
(b) a description of the period of time within which, and the frequency with which, each high-risk AI system is intended to be used;
(c) the categories of natural persons and groups likely to be affected by its use in the specific context;
(d) the **specific risks of harm** likely to have an impact on the categories of natural persons or groups of persons identified pursuant to point (c) of this paragraph, taking into account the information given by the provider (...);
(e) a description of the implementation of human oversight measures, according to the instructions for use;
(f) the **measures to be taken in the case of the materialisation of those risks**, including the arrangements for internal governance and complaint mechanisms».

From an OSH perspective, the risks that can harm workers (created mainly by psychosocial or work organisation factors) should be included in this fundamental rights impact assessment (as paragraphs d. and f. of article 27 of the AI Act specify).

Therefore, although enterprises that use AI systems for algorithmic management need to consider other fundamental rights (e.g., privacy and non-discrimination), it is undeniable that they will need to identify hazards and evaluate OSH risks and implement preventive measures.

In summary, enterprises that use AI systems for algorithmic management will need guidelines to evaluate OSH risks and plan preventive actions. However, the first step to developing any practical tool is to know what their main risks and hazards are, but it would also be appropriate to consider the potential positive effects for OSH of these AI systems for worker management.

The PEROSH´s Algorithmic Management and AI-based systems, or ALMA-AI project, aims to contribute to the aforementioned challenge, as the project's initial objective highlighted:

> The ALMA-AI project has the purpose of understanding the "soul" (*alma* in Spanish) of Algorithmic Management, identifying which are some of its consequences (OSH risks and opportunities), but also to contribute to the future of the development of ethical AI or other advanced systems used to organise workers. In other words, our project aims to delve into the OSH implications of the use of AI or other complex systems based on digital devices, which are dedicated to the organisation of work or workers management.

1.2. Methodology: Grey literature and scientific review

There were two main research methods planned in the ALMA-AI project: a literature review and a statistical data analysis[1]. However, in the end, the efforts of the research team of the project were focused on the literature review. Specifically, a comprehensive review has been carried out of scientific journals, but also of grey literature reports of recognised institutions related to the OSH implications of algorithmic management.

On the one hand, it is important to highlight that, initially, the ALMA-AI project literature review aims to identify evidence in each language of their participating institutions' countries. For that purpose, the Keywords of the EU-OSHA research on AI for worker management were translated and used (Christenko et al., 2022a, p. 86), adding new ones. However, the different language searches were very poor. Therefore, although an important effort was made in this first activity, the ALMA-AI team decided to focus only on the literature review´s search in English.

[1] The statistical data analysis as a research method was planned to identify datasets for statistical analysis to generate quantitative evidence. However, the existing surveys and datasets during the time of the research at a European level (or for the countries of the ALMA-AI project institutions) that were useful to analyse the association between OSH implications (psychosocial mainly) and algorithmic management have already been used: the Eurofound and Cedefop survey (Kinowska & Sienkiewicz, 2023), or those carried out by EU-OSHA, ESENER-3 (Urzi & Curtarelli, 2021), and the OSH Pulse survey (Pesole, 2023). The results of these data analyses will be described in *section 4.1.2* of this report.

On the other hand, independently of the previous endeavour, it is necessary to note that the ALMA-AI project used a specific **research question** and **literature review** framework:

- Research Question: *What are the OSH implications regarding psychosocial or work organisation factors for workers who are coordinated, evaluated, supervised or/and compensated/penalised by algorithmic management?*
- PEO (Population, Exposure, Outcome) framework**:**

PEO	Definition	ALMA-AI research
Population	Who is the research question focused on?	Workers who are organised or controlled by ALMA
Exposure	What is the issue we are interested in?	Algorithmic management (*see section 2.1. for its conceptualisation*)
Outcome	What, in relation to the issue, do we want to examine?	Psychosocial or work organisation OSH implications

- Online search engines: Web of Science (WoS)
- Search string(s)[2]:

  1st: "Algorithmic Management" AND "Artificial Intelligence" as a Topic

  2nd: "Algorithmic Management" in Title OR Abstract
- Search period: From 2022 to 2024
- Language: English (other languages accepted according to project participants' languages)
- Eligibility criteria: Peer-reviewed articles of periodic scholarly journals for the scientific review, and reports of recognised institutions (EU-OSHA, JRC, ILO, OECD) for the grey literature, considering as exclusion/inclusion criteria[3]:
  a) Focused on algorithmic management
  b) Useful to analyse the OSH/psychosocial implications
  c) Contribution with direct evidence (e.g., data analysis, interviews, case study).

[2] Due to the lack of precision of the 1st search (i.e., many articles focused on other AI applications, not for the semi-automation of management functions), the team agreed to carry out an additional search using the 2nd search.

[3] A filtering process was conducted with the reading of the Abstract using the first two eligibility criteria; the third one was used only in the scientific review for the final selection of papers.

- Study selection:

In the grey literature, the publications were gathered by reviewing recognised institutions' webpages, but also through searches in general engines (Google and Google Scholar).

First, in the scientific review, a filtering process to select papers with the two mentioned exclusion/inclusion criteria was conducted, dividing papers into equal groups and assigning them to each Institute. Two reviewers from each Institute independently performed the filtering process. The articles that remained after this filtering process were downloaded in their full-text version and allocated again between institutes (an equal number for each institute).

Second, by reading the articles, each institute needed to answer different questions in an Excel file (How ALMA or AI is studied? Can any association be identified between ALMA and risks/OSH? Underlying discussion or topic on ALMA-AI and its effects? Quality assessment, including methodology and quantification? Which is the study work domain, traditional or platform work?), adding a final comment with a proposal for inclusion (Yes or No). In case of disagreement on the inclusion/exclusion of one or more papers (in doubt), the two reviewers of each Institute discussed their points of view; if no consensus was still reached, a discussion among the research group was made to solve the conflicts with the view to define the final list of selected papers.

Third, an in-depth analysis of the selected publications was conducted, gathering Information Sheets with relevant data (authors, title, country, methodology, ALMA uses, psychosocial factors, OSH implications, main results) in the case of the scientific review.

On the one hand, in the **grey literature review**, a total of **14 reports were selected** considering 17 publications identified (see right side of the *Figure 1*), underscoring also the preliminary cutting-edge research the of EU-OSHA and JRC (both observer partners of the project), with their **initial two reports** (EU-OSHA, 2022a; JRC, 2023) being a starting point for the ALMA-AI research to understand algorithmic management uses and their OSH implications. In addition to the use of these grey literature publications to understand ALMA and its potential effects (see Chapters 2 and 3 of the report), it is necessary to consider that **6 reports have new evidence** (period 2022-2024) on the OSH implications and psychosocial factors involved, and were included in the final analysis (so their main results are described throughout Chapter 4).

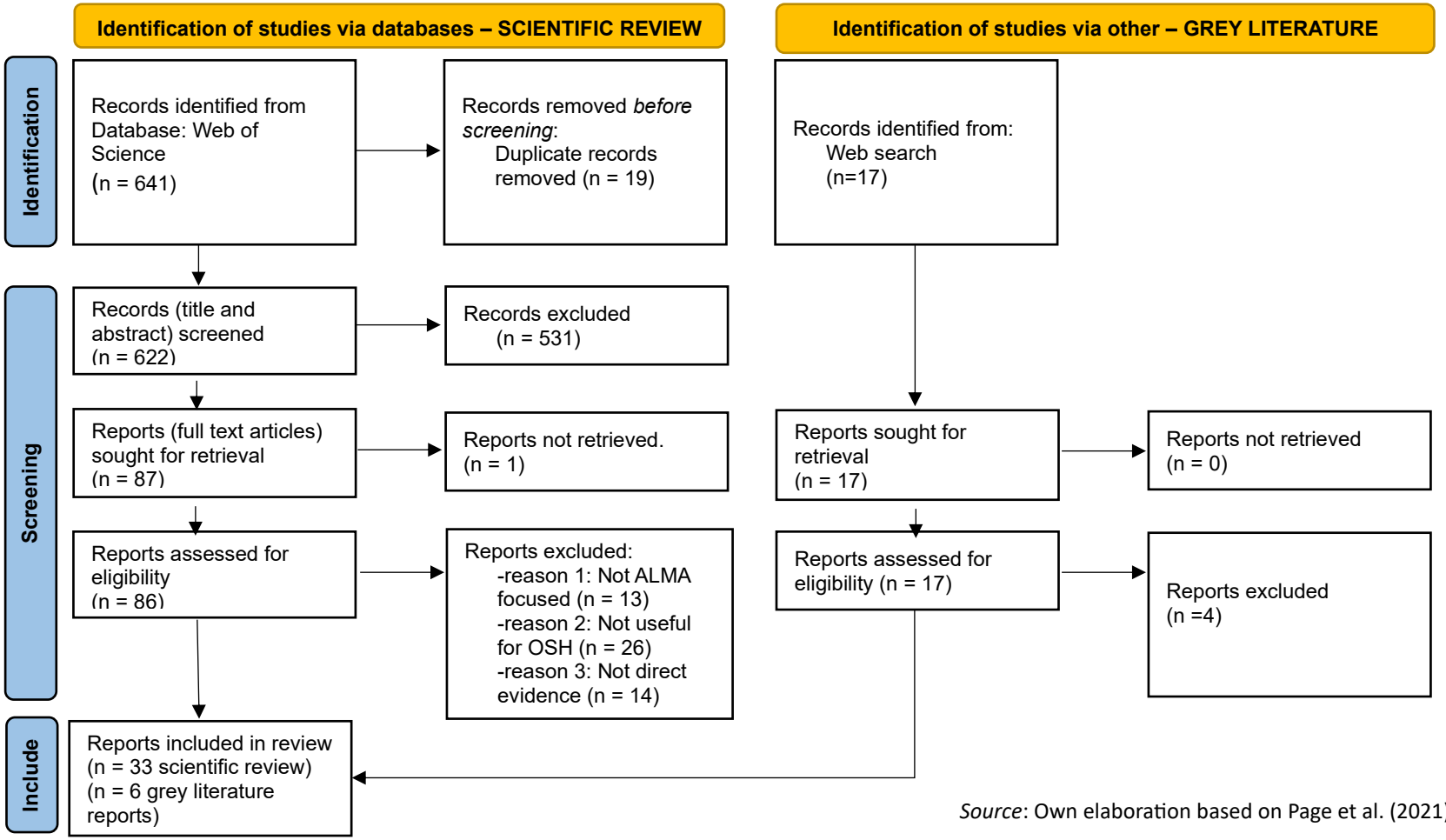
On the other hand, as shown in the PRISMA flow diagrams of the next pages, the results of the scientific literature review were the selection of 33 total peer review articles (see *Figure 1*), considering 15 papers with the search of ALMA&AI terms in Web of Science as Topic (*Figure 2*) and 18 evidence-based peer review articles with the ALMA search (*Figure 3*).

The literature review search results are congruent with the decision to carry out an additional one, only using the "algorithmic management" (ALMA) term to identify those articles that include it in their Titles or Abstracts. As it is clear comparing both diagram flows (*Figure 2* with *Figure 3*), the initial search, which includes also the term "Artificial Intelligence" (AI) with ALMA as topic, although it identifies a higher number of scientific publications (489 references are screened), they are mainly related to other AI applications, not design for managerial purposes. Consequently, although the only ALMA search has 152 references to filter, the number of final selected publications is almost the same as the ALMA&AI search, considering that even the 2nd search (using only ALMA) has added repeated references with that one.

Beyond the precision of the search to identify articles to analyse OSH and new evidence about ALMA effects, it is necessary to reinforce that, in the **scientific literature review** (see *Figure 1*), in total **641 references** were screened, then **pre-selecting 86 papers** and **finally selecting 33 peer-reviewed articles** published in scientific journals, which present new evidence on the association between the uses of ALMA and psychosocial factors that trigger different implications and impacts on OSH.

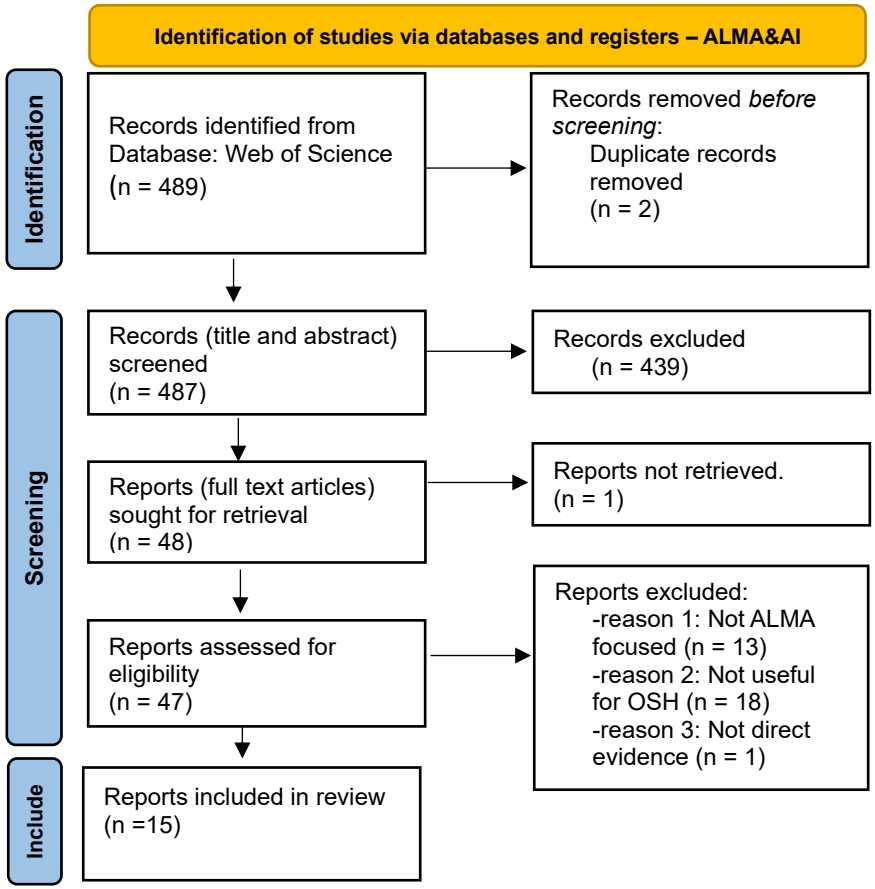
In summary, considering both the grey literature and the scientific review, **39 publications** were selected, which **contain new evidence** about the OSH implications of ALMA from 2022 to 2024. The final analysis of the publications was implemented after a filtering process of more than 650 abstracts of mainly scientific articles, but also reports of cutting-edge institutions.

Figure 1. Diagram flow of the comprehensive literature review (scientific and grey literature)



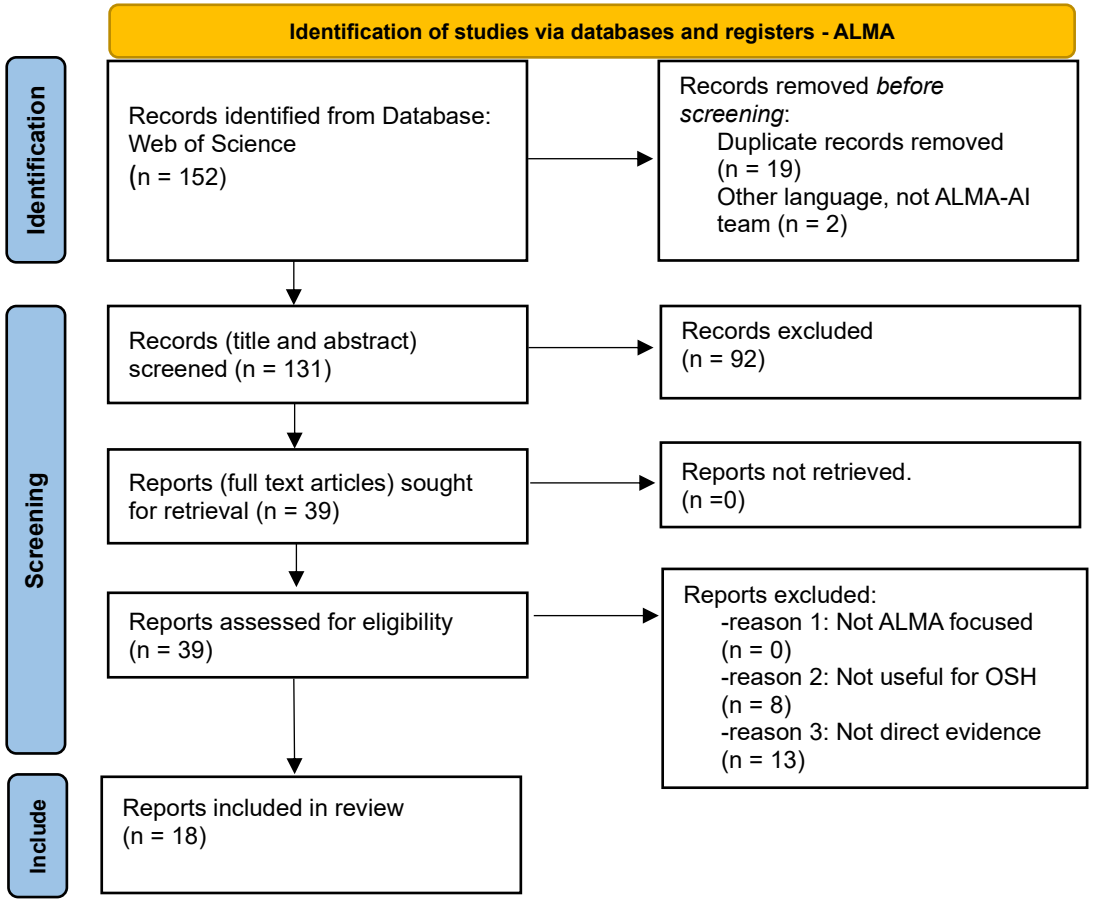
Source: Own elaboration based on Page et al. (2021)

Figure 2. Diagram flow of scientific review of "algorithmic management" and "artificial intelligence" (ALMA&AI) as a topic in Web of Science



Source: Own elaboration based on Page et al. (2021)

Figure 3. Diagram flow of scientific review of "algorithmic management" (ALMA) as Title or Abstract in Web of Science, Scopus and PubMed



Source: Own elaboration based on Page et al. (2021)

II. THEORETICAL APPROACH

2.1. Algorithmic Management (ALMA) or AI for worker management

Heidi Lahti (FIOH, Finland) & Jorge Martín (INSST, Spain)

After analysing several articles and reports in the field, "Algorithmic Management" (ALMA in the rest of the document) was defined in the project as the use of complex digital systems or AI to manage workers. Therefore, ALMA was conceptualised as **the use of computer-programmed digital systems to (semi) automatically perform management functions** that traditionally had been in charge by managers or supervisors. This conceptualisation is almost the same that the one recently published by Anna Milanez, Annikka Lemmens and Carla Ruggiu from OECD (2025), who consider ALMA as «the use of software, which may include artificial intelligence (AI), to fully or partially automate tasks traditionally carried out by human managers» (p. 3). Therefore, ALMA would include all work processes (see later in this section ALMA functions or uses) which are involved in managing the workforce in an organisation, including coordination and allocation of work procedures and tasks; control of their accomplishment or surveillance of how are carried out; evaluation the performance of workers; and compensations or penalisations depending of the work results. It is important to highlight that a **specific function of ALMA was dismissed** to analyse in the project: the selection process for **hiring workers**. Although it is a relevant function that is increasingly automated, for example by AI, it is excluded in most of the EU countries as a part of formal work relationships and, therefore, is not an OSH field *per se*. It is relevant to take into account because, as mentioned, this is an emerging management function that is more and more automated by digital complex systems, especially by AI[4].

Otherwise, it is relevant to note that the inclusion of AI in ALMA is still not entirely clear, probably because the companies that develop software designed to manage workers want to protect their added value, and maybe also because nowadays, arguing that a product is built on AI could be an advertising claim. Regardless, some of the pioneer companies that used ALMA, for example digital labour platforms such as Uber, has been using AI techniques (machine learning or neural networks) since at least 2017 (Turakia, 2017; Zhu & Laptev, 2017).

[4] As an indicator, an analysis of the use of AI in Human Resources functions covered in the academic field (Bujold et al., 2024), shows that 40% of the scientific papers related to the issue (N=79) are focused on "Talent acquisition" (n=32), representing around 20% each those that deepen in "Performance Evaluation" (n=18), "Workforce Planning" (n=15), and "Talent Management" (n=14), and only a 10% AI-related papers focused on "Health and Wellbeing" (n=8) or 4% in the case of the human resource function of "Compensation" (n=3).

The above reveals that enterprises that started with novel ALMA systems to organise workers have been using AI in their business models for years, before the so-called "AI hype" that emerged since the launch of ChatGPT and other generative AI tools in 2022. Therefore, there is still a need to clarify which ALMA software used to manage workers incorporates AI or which does not. This is particularly relevant because AI can fundamentally amplify how these systems affect workers, for instance, by enabling more continuous and adaptive forms of surveillance and control that not only monitor but also aim at modifying worker behaviour (Mettler, 2023).

Getting back to the abovementioned conceptualisation of ALMA, it is important to point out that it is built upon different reports of recognised institutions, but also with the contributions of relevant authors or researchers in this particular academic field. On the one hand, according to Enrique Fernández-Macías, Cesira Urzi, Samy Wright, and Annarossa Pesole (2023), the team responsible for the AMPWork survey (see *section 3.1*) from the Joint Research Centre (JRC) of the European Commission, *algorithmic management* refers to the «use of computer-programmed procedures, which may be powered by artificial intelligence or not, to coordinate labour input in an organisation» (p. 11). However, they differentiate algorithmic management from "digital monitoring (or surveillance)", which corresponds to any collection and processing of data from workers with the purpose of influencing or managing them. However, they warn that both phenomena tend to appear together since algorithmic management usually presupposes the use of significant amounts of data, and digital monitoring uses algorithms when it is intended to be used for management (Fernández-Macías, et al., 2023). Nevertheless, for the purpose of the ALMA-AI project, both concepts are considered as part of ALMA, as it is argued considering other authors' conceptualisation, but also because "surveillance" or "monitoring" have been categorised as part of the traditional management functions.

Regarding the previous argument, some of the most prominent authors in the scientific literature of the field, who work together to publish different peer-reviewed articles, specifically Xavier Parent-Rocheleau, Antoine Bujold and Marie Claude Gaudet of HEC Montreal (Canada), or Sharon Parker and Marylène Gagné of Curtin University (Australia), defined *algorithmic management* (in a similar way than Fernández-Macías and the JRC team) as «the use of programmed algorithms, often powered by artificial intelligence, by an organisation to partially or completely execute workforce management functions (i.e., hiring and firing, coordinating work, monitoring performance)» (Gagné et al., 2022, p. 248) adding later explicitly to their definition «management functions and control» (Parent-Rocheleau et al. 2024, p 27.).

Moreover, they incorporate monitoring or surveillance as one of the **dimensions** of an ALMA questionnaire, which initially included “algorithmic” (Parent-Rocheleau et al. 2024, pp. 27-28):

- «***Monitoring*** refers to the use of algorithmic systems by organisations to collect, aggregate, and report data, usually in real time, on workers' behaviors and actions or on their work (…);
- ***Goal setting*** refers to the use of algorithmic systems to assign tasks, organise employees' work, or set performance or productivity targets (….);
- ***Scheduling*** refers to the use of algorithmic systems to determine or influence employees' schedules or working times (….);
- ***Performance rating*** refers to the use of algorithmic systems to appraise, rate or rank workers' performance or productivity, usually in real time, typically through the calculation of several metrics or quantified indicators (….);
- ***Compensation*** refers to the use of algorithmic systems to calculate workers' pay, typically based on algorithmically managed conditions and metrics, and according to various indicators such as the number of tasks carried out, individual performance, customer satisfaction, or other data associated with, directly or indirectly, productivity;
- ***Job termination*** refers to the use of algorithmic systems to decide, implement, or facilitate job termination based on unsatisfying ratings».

Previous categories and concepts are the guiding definitions of the ALMA-AI project research. However, it is necessary to note that there are several more, including in papers of other prominent authors in the field, such as Min Kyung Lee, nowadays a professor of the University of Texas at Austin (USA), who coined the term "algorithmic management” to the phenomenon and, jointly with her colleagues at that time in the Carnegie Mellon University (Daniel Kusbit, Evan Metsky and Laura Dabbish), in 2015 defined ALMA as a set of software algorithms that assumed managerial functions (see *Figure 4* below), in workplaces in which «human jobs are assigned, optimised, and evaluated through algorithms and tracked data» (Lee et al., 2015, p. 1603), being a similar conceptualisation than the chosen one by this ALMA-AI project, which includes as part of the phenomenon the managerial function (semi-automated by algorithms or AI) of data tracking (monitoring or surveillance).

However, other approaches do not incorporate or consider at the same level of importance the ALMA functions previously highlighted (Parent-Rocheleau et al. 2024). For example, another referent author in the field, Jeroen Meijerink, defined ALMA as a "system of control" with his colleague Tanya Bondarouk of the Twente University (The Netherlands), highlighting the digital surveillance or ALMA monitoring function as crucial (Meijerink & Bondarouk, 2023). Both definitions or conceptualisation are included with others by Meijerink himself with Laura Lamers and Giorgio Rettagliata (Lamers et al., 2024), showing a plethora of definitions that exemplify the variety of conceptualisations, although in the majority (see *Figure 4*), there is a tendency to either conceptualise ALMA focusing on a control perspective (or oversight, surveillance, monitoring, data tracking) or as a new form of work organisation (or coordination, management or assignment of activities). Importantly, Lamers et al. (2024) call for a broader research agenda that considers human agency and adopts a more human-centered perspective on ALMA instead of narrowly focusing on its control functions and economic efficiency.

Figure 4. Definitions of Algorithmic Management in scientific literature (2015-2023)

Author(s)	Year	Definition
Lee, Kusbit, Metsky and Dabbish	2015	"Algorithms that assume managerial functions and surrounding institutional devices that support algorithms." (p. 1)
Möhlmann and Zalmanson	2017	"Oversight, governance, and control practices conducted by software algorithms over many remote workers [...] characterized by continuously tracking and evaluating worker behavior and performance, as well as automatic implementation of algorithmic decisions." (p. 4)
Leicht-Deobald, Busch, Schank, Weibel, Schafheitle, Wildhaber and Kasper	2019	"Algorithms designed to support and govern HR decisions." (p. 2)
Wood, Graham, Lehdonvirta and Hjorth	2019	"An extension of 'customer management' strategies." (p. 62)
Duggan, Sherman, Carbery and McDonnell	2020	"A system of control where self-learning algorithms are given the responsibility for making and executing decisions affecting labor, thereby limiting human involvement and oversight of the labor process. It replaces some of the tasks and processes that workers typically engage with by using algorithms that are developed by the very same individuals' data on the platform." (p. 119)
Gal, Jensen and Stein	2020	"Computational techniques that leverage digital data from multiple organizational areas to reflect different facets of members' behavior." (p. 1)
Cheng and Hackett	2021	"HRM algorithms are computer programs of a heuristic nature that use economical input of variables, information, or analytical resources to approximate a theoretical model, enabling an immediate recommendation of screening, selection, training, retention, and other HR functions." (p. 8)
Jarrahi, Newlands, Lee, Wolf, Kinder and Sutherland	2021	"Socio-technical process emerging from the continuous interaction of organizational members and the algorithms that mediate their work." (p. 2)
Möhlmann, Zalmanson, Henfridsson and Gregory	2021	"The large-scale collection and use of data on a platform to develop and improve learning algorithms that carry out coordination and control functions traditionally performed by managers." (p. 2001)
Newlands	2021	"An assemblage of computational processes, which automatically generate data, evaluate worker behavior and assign labor activities." (p. 723)
Meijerink and Bondarouk	2023	"System of control that relies on machine-readable data and software algorithms that support and/or automate managerial decision-making about work." (p. 3)

Source: Lamers, Meijerink & Rettagliata (2024, p. 415).

Another key reference for understanding ALMA is the work by Sara Baiocco, Enrique Fernández-Macías, Uma Rani and Annarosa Pesole (2022). While their conceptualisation of ALMA aligns with prior definitions, this JRC-ILO report offers an alternative perspective on how its key functions can be categorised. Rather than drawing on the six ALMA functions introduced earlier (Parent-Rocheleau et al., 2024), the JRC-ILO report links ALMA's core functions to five classical management functions: planning, staffing, commanding, coordinating, and controlling (Baiocco et al., 2022, p. 6). The JRC-ILO report also highlights that ALMA first emerged as an intrinsic feature of digital labour platforms, where it has become essential for the efficient coordination of highly complex work processes involving a multitude of small labour inputs (Baiocco et al., 2022, pp. 17, 20). This platform-based model has since expanded into regular workplaces, influencing industries like logistics, retail, and customer service, where ALMA is increasingly integrated, for instance, into scheduling and monitoring (*ibid*, p. 17). A recent bibliometric review also reflects this development, identifying ALMA as a central theme in the digital transformation of work, especially in the context of online platforms but increasingly in traditional employment settings as well (Subramony et al., 2023). However, in these regular work settings, ALMA does not function identically to platform work (see *Chapter 3*), as it interacts with pre-existing organisational structures that shape its implementation (Baiocco et al., 2022, p. 17).

Both the JRC-ILO report and other recent contributions underline the importance of understanding ALMA not merely as a technical system, but as a socio-technical process embedded in broader institutional and organisational contexts (Baiocco et al., 2022, p. 8). For instance, Cameron et al. (2023) emphasise the importance of integrating insights from multiple fields, including information systems, organisational behaviour, ethics, and sociology, to understand ALMA as both a technical and socio-organisational phenomenon. Accordingly, the impact of ALMA on workers is shaped not only by its technical features but also by how, and for what purposes, it is designed and used. This is also acknowledged in the conceptual model proposed by Parent-Rocheleau and Parker (2022), which identifies algorithmic transparency, algorithmic fairness, and the possibility of human influence as key socio-technical moderators shaping the relationship between ALMA and its impacts on work and workers. These moderators can also be understood as ethical dimensions of ALMA and AI use at work, reflecting broader concerns raised in ethical risk models that shape how AI-based decision-making impacts individuals and society (Guan et al., 2024).

2.2. Psychosocial factors approach to deepen a new form of work organisation

Jorge Martín (INSST, Spain)

Although different authors pointed out the excessive attention to control and efficiency in the academic field (see previous *section 2.1*), it is necessary to reinforce the idea that **ALMA operates as a new form of work organisation**, considering it in a wide range approach, that includes not only surveillance or monitoring to control workers, but also allocation of schedules or tasks, and performance rating systems to evaluate them. Therefore, the risk factors that can be mainly identified in the ALMA literature concerning OSH most probably have a psychosocial nature. **Psychosocial risk factors or hazards** are understood in the OSH field as those working conditions encompassing both the design and organisation of work, as well as social relationships in the workplace, that have the potential to harm workers (Cox & Griffiths, 2005).

In the past decades, it has been corroborated that inadequate psychosocial working conditions are linked with stress and different health problems, such as heart disease, depression, and musculoskeletal disorders (MSDs). As concluded by Stavroula Leka and Aditya Jain (2010), in their study for the World Health Organization, «a growing body of evidence demonstrates that a poor psychosocial working environment and work-related stress can have both a direct and indirect impact on workers' physical health and mental well-being» (p. 63). Otherwise, when the same psychosocial factors (e.g., job content, workload, autonomy, interpersonal relationships, etc.) are properly managed, they can improve the well-being and motivation of workers, both of which could be considered as the opposite of psychosocial risks. In this context, some referent authors conceptualised critical factors (that could influence stress) as motivational ones when they appear in a positive form. For example, Karasek argues that high control over work generates "active jobs" that would be associated with motivation and learning for workers (Karasek, 1979). On the other hand, as Hanna Kinowska and Łukasz Jakub Sienkiewicz (2023) pointed out, for some perspectives, psychological "well-being" includes aspects such as «positive interpersonal relationships, a sense of freedom, autonomy, a sense of purpose in life and opportunities to develop one's potential» (p. 24), which could mostly be understood as positive measures of psychosocial factors.

Coming back to the evidence about the importance of psychosocial risks or hazards in OSH, there are very relevant theories or models to understand them. One of the most cited was the **Demand-Control-Support (DCS)** model of occupational stress, initially developed by Robert Karasek (1979) and then adjusted by Jeffrey Johnson and Ellen Hall (1988), which argues those

jobs that entail high demands and a lack of control over the work process, together with poor social support, will produce a greater probability of damaging the health and reducing the well-being of the worker, by generating greater "psychological strain", a concept used in the initial approach that was considered by its own author as "stress-management model" (Karasek, 1979). Furthermore, Marcus Fila (2016) pointed out that these work characteristics negatively affect health since they lead workers to «continually devoting high amounts of cognitive resources to meeting demands, which would result in an elevated level of physiological arousal and increased cardiovascular and nervous system attention» (p. 16). Another important model has been the **Effort-Reward Imbalance (ERI)** model developed by Johannes Siegrist (1996), which assumes that «experiencing lack of reciprocity in terms of high cost spent and low gain received in turn elicits negative emotions of anger and frustration and associated bodily stress reactions, with adverse long-term consequences for health and well-being» (Siegrist, 2017, p.26). Nevertheless, in recent years, researchers have turned their interest to the **Job Demands-Resources (JD-R)** model, elaborated initially by Evangelia Demerouti, Arnold Bakker, Friedhelm Nachreiner, and Wilmar Schaufeli (2001) to understand burnout. Subsequently, the model was transformed into an alternative to predict well-being at work (Bakker & Demerouti, 2007). Arguing that they considered the strengths and weaknesses of DCS and ERI models, the authors of the JD-R model pointed out it is useful to analyse stress, but also well-being, as they argued it is focused on both negative and positive indicators (of psychosocial factors), able to apply also in a wide range of occupations (*idem*). The last JD-R model assumes that «high job demands lead to strain and health impairment (the health impairment process), and that high resources lead to increased motivation and higher productivity (the motivational process)» (Schaufeli & Taris, 2014, p. 43).

It is relevant to note that the JD-R model has been used in the scientific literature of algorithmic management, being especially clear in the case of the **theoretical framework proposed by Parent-Rocheleau and Parker (2022)**, which considers explicitly the assumptions of the JD-R model, although paying attention only to their positive outcomes (engagement, motivation and performance), and dismissing other consequences of the relationship between job demands or resources (e.g. burnout). These authors, with their colleagues in HEC Montreal and Curtin University (see *section 2.1*), prioritise the study of positive consequences of ALMA, linking with its influence in "work design", construct that Sharon Parker herself defined as the «content and organisation of one's work task, activities, relationships, and responsibilities» (cited in Parent-Rocheleau & Parker, 2022, p. 1), being this concept almost equivalent to the definition of psychosocial risks highlighted at the beginning of this section.

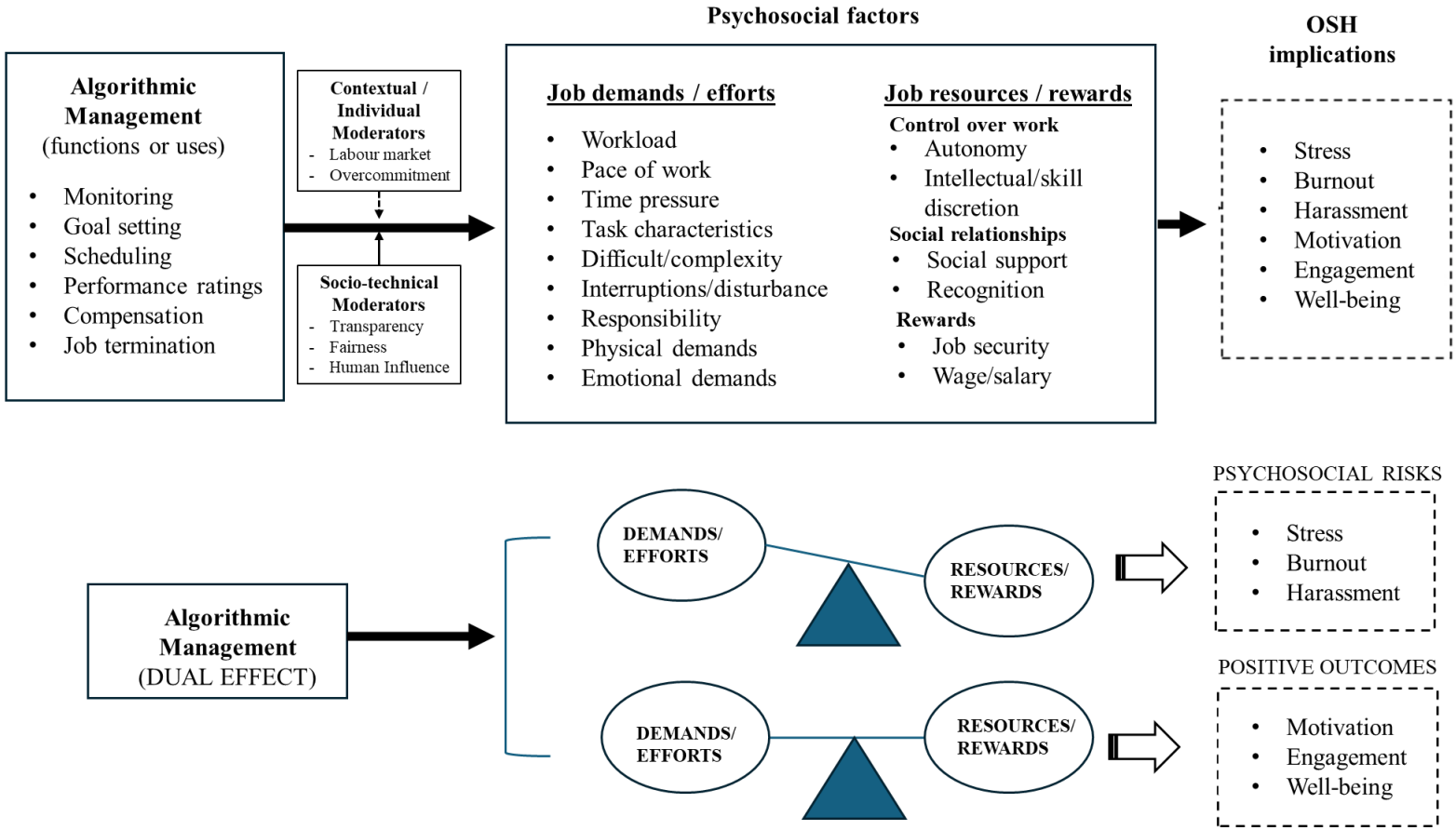
The mentioned authors also underline that the «**existing research** on algorithmic management tends to suggest that it generates **more negative than positive outcomes** for workers», specifically stand out that the decrease of the autonomy over work and the power asymmetry in information associated to ALMA result in negative emotions, perceived unfairness, lack of trust, lower job and life satisfaction and reducing engagement in work (*ibid*, p.2).

To **fill the gap** and focus on its positive consequences, the authors argued that they «address these limitations by reviewing the findings from empirical and descriptive studies» on ALMA, but remarking that «considerable evidence shows that these job resources and demands, in turn, affect workers´ **motivation, well-being and performance**» (*idem*).

In essence, Parent-Rocheleau and Parker (2022) pointed out that their framework «draws mainly on the popular job demands-resources model (JD-R model: Demerouti, Bakker, Nachreiner, & Schaufeli, 2001)» (*ibid.*, p. 4), but **focusing only on positive outcomes**. However, it is necessary to reinforce that the original model they used was initially developed to understand "burnout", in which the job demands that play a significant role are the same that create stress at work in different occupations.

As *Figure 5* summarises, adjusting the Parent-Rocheleau and Parker (2022) framework, the ALMA-AI project focused on both types of outcomes, positive and negative, but dismissed those related to issues not strictly concerning OSH (e.g., performance). The JD-R model suits very well to the purpose of the project, but the proposed comprehensive model includes additionally definitions and concepts of the other two models (DCS and ERI), because it is important to bear in mind that the most well corroborated factors, as the JD-R model authors recognised, although to criticise the excessive attention of the researchers in them (Bakker & Demerouti, 2007), are related to job demands, such as work pressure or efforts. For this reason, but also to strengthen the understanding of the negative impact of ALMA effects (namely, psychosocial risks), *Figure 5* highlights, as explained below, **well-known psychosocial factors that can create OSH implications, such as risks, but also opportunities**.

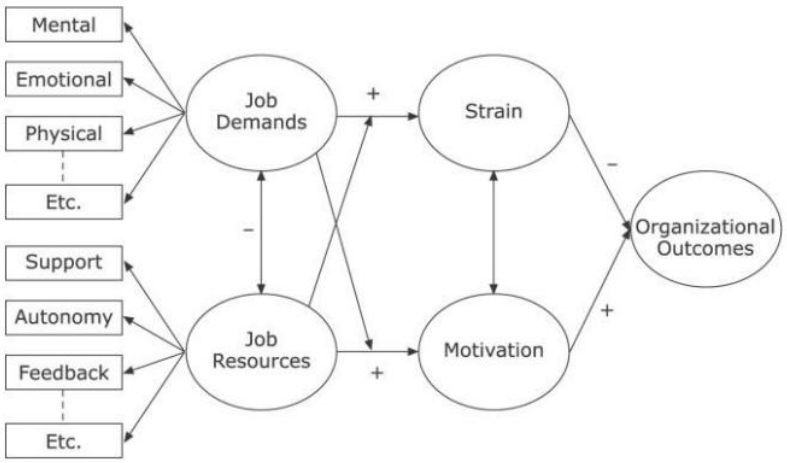
Figure 5. ALMA-AI comprehensive model or approach to analyse psychosocial or work organisation factors in algorithmic management



Source: Own elaboration based on Parent-Rocheleau & Parker (2022, p.2) and psychosocial risk models (Karasek, 1979; Siegrist, 1996; Demerouti et al, 2001)

The comprehensive model to analyse the OSH effects on algorithmic management (*Figure 5*) assumed the same hypothesis as the JD-R model, which in turn is also equivalent to some extent to the ERI model conceptualisation (see *Figure 5* below compared to *Figure 6* and *Figure 7*). Namely, the model assumes that when higher job demands overcome the resources that the workers can mobilise, the probability of suffering psychosocial risks (stress and burnout, but also, by extrapolation, other such harassment) or the likelihood of other negative health and safety consequences (e.g., fatigue or accidents) increases. On the other hand, when the resources of the workers match or surpass the job demands, it is assumed that the probability of experiencing well-being and motivation, or reinforcing their engagement, is higher. Regarding these assumptions, some authors consider that the JD-R model has become popular among researchers because it includes this potential dual effect (Schaufeli & Taris, 2014). The JD-R model argues that the **same psychosocial factors could create different outcomes** depending on how they are managed in a "dual process", in which «two different underlying psychological processes play a role in the development of job strain and motivation» (Bakker & Demerouti, 2007, p. 313). As *Figure 6* visualises, on the one hand, inadequate work design or chronic job demands, such as excessive work overload or emotional demands, can «exhaust employees' mental and physical resources and may therefore lead to the depletion of energy (i.e. a state of exhaustion) and to **health problems**» (*Idem*), in the "health impairment process". On the other hand, appropriate job resources, as autonomy or support, lead to a "motivational process" that increases **engagement and performance**, as they can boost learning or development (intrinsic motivation) and focus the worker on achieving goals and rewards (extrinsic motivation).

Figure 6. The Job Demand-Resources (JD-R) model dual process

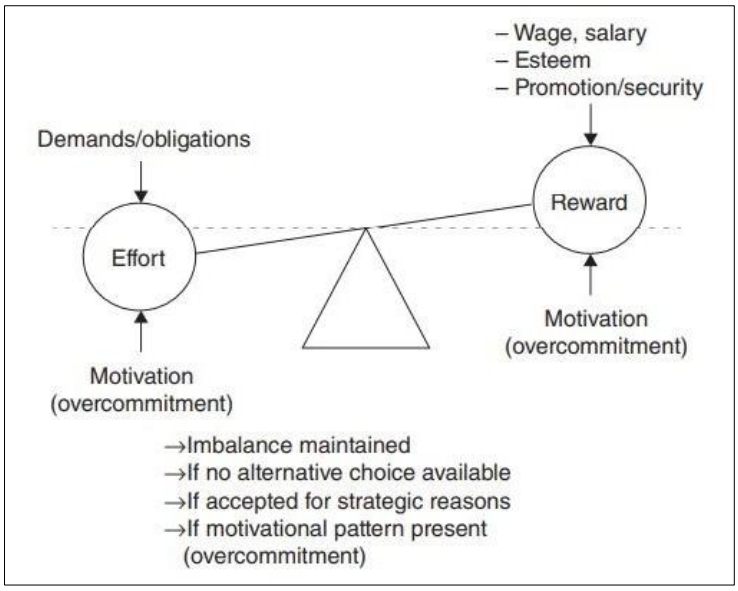


Source: Bakker & Demerouti (2007, p. 313).

Additionally, the JD-R considers different interactions between job demands and resources (see also *Figure 6*). For example, it assumes that job resources may moderate the impact of job demands, reducing the probability of suffering stress. As Bakker and Demerouti (2007) pointed out, the JD-R model assumes the "buffer hypothesis" of the DCS model but emphasises that while in that model «control over the execution of tasks (autonomy) may buffer the impact of work overload on job stress, the JD-R model expands this view and states that different types of job demands and job resources may interact in predicting job strain» (p. 314).

The ERI model of Siegrist (1996, 2017) also highlights that the **imbalance between efforts and rewards could generate stress and health issues** (*Figure 7*), but some specific circumstances can moderate them. One of them is "dependency", namely, when the worker has no other option in the labour market. Another is the "strategic choice" to experience the imbalance consequences during a certain time, thinking that, in the future, it will obtain gains in exchange for the efforts made in the present (Siegrist, 2017). This last specific situation reveals that for the ERI model, imbalance could occur not only by external demands (e.g. poor working conditions), but also by intrinsic ones, such as the personal "over-commitment", another situation Siegrist highlights, as a pattern of motivation to push forward for high achievements in work, searching for social approval or esteem, even if it is not create by high (external) job demands.

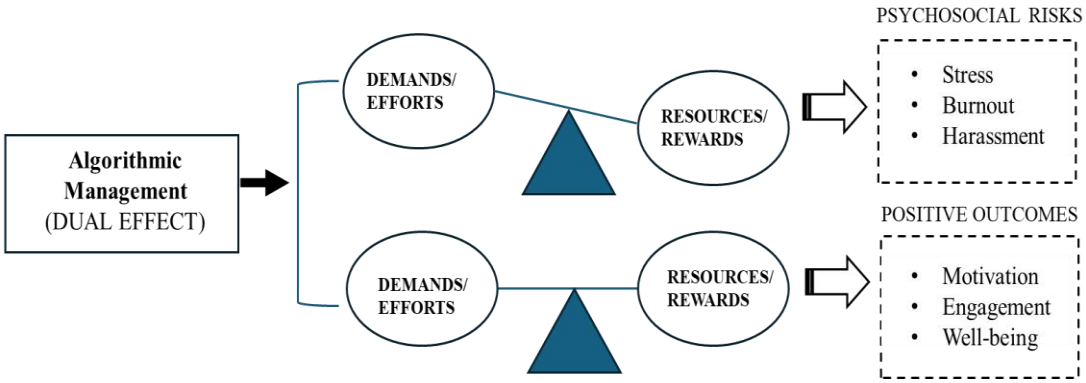
Figure 7. The model of Effort–Reward Imbalance (ERI) at work



Source: Siegrist (2017, p. 27).

In summary, it seems that the JD-R, DCS, and ERI models assumptions concur to the point that when an imbalance between job demands and resources or rewards occurs, it leads to consequences, being negative when the demands surpass the resources or rewards, and positive outcomes in the contrary, when resources or rewards are higher than demands. This dual effect is synthesised in *Figure 8*, which is part of the comprehensive model shown before (*Figure 5*). Its visualisation comes clearly from the one Siegrist (2017) used for the ERI model (*Figure 7*), but is also inspired by the dual process (*Figure 6*) explained by Bakker and Demerouti (2007).

Figure 8. The dual effect of algorithmic management



Source: Own elaboration based on Siegrist (2017, p. 27) and Bakker & Demerouti (2007).

Regarding the assumption of this dual effect, it is relevant to note that some of the most prominent authors in the ALMA academic area, such as the professor Jeroen Meijerink (see *section 2.1*) and his colleague Tanya Bondarouk (2023), although not using OSH terms, defend what they called the "duality of algorithmic management", highlighting that it can restrain or enable autonomy and value for workers, conceptualizing this last concept as monetary benefits but also non-monetary, such as social relationships, learning or enjoyment that workers can feel. Namely, in the research field of ALMA, the dual effect has also been remarked, considering, on the one hand, that it could restrain autonomy or value for workers, which can both be categorised as psychosocial factors, specifically, as job resources or rewards (as will be realised with the definitions described below). Therefore, ALMA can also lead to psychosocial risks (if job demands are high). However, on the other hand, these authors consider that ALMA can have positive consequences. They also argued for the need to put more effort into "Human Resources Management" (HRM) research agenda to delve into positive outcomes. In summary, in their own words, «desired consequences of HRM algorithms to workers co-exist alongside the undesired consequences that the literature has mostly reported on» (Meijerink & Bondarouk, 2023, p. 1).

Beyond the theoretical hypothesis of the JD-R model and the other two models (DCS and ERI), one another and a crucial reason for using them to feed the approach proposed by Parent-Rocheleau and Parker (2022) is to identify precisely the psychosocial factors that could have OSH implications in the evidence-based scientific literature, which use other terms to describe them.

First, the DCS model used different definitions and measures that are appropriate to analyse psychosocial factors, to the extent that a solid amount of evidence demonstrates the relevance of the factors included in the model. To consider it, and limiting only to the period until 2007, at least 146 empirical studies were carried out to corroborate the DCS model[5]. The psychosocial risk factors of the model are defined as follows, adding different measures or indicators:

- ***Demands*** are the characteristics or working conditions that require physical or mental effort, which shape together the overall workload (Karasek, 1979; Fila, 2016).

  Measures or indicators of job demands are: time pressure; pace of work; level of difficulty or complexity; and task predictability. However, the job demands concept should include other indicators such as: conflicts generated by the organisational role; physical demands; and emotional demands (Karasek, 1979; Häusser et al., 2010).

- ***Control over work*** refers to the individual's beliefs or perceptions about the ability to influence one's own work environment (Fila, 2016). Or as Karasek (1979) understood it, the so-called "job decision latitude" is «the working individual's potential control over his tasks and his conduct during the working day» (pp. 289-290). This dimension of control in the model considers two subfactors or measures:

  i) "Decision authority", or ***autonomy*** to decide about work, which can be conceptualised as the freedom of how to do it, but also the capacity to choose when or where it is done.

  Karasek (1979) initially used variables such as: freedom of how to work; allowing a lot of decisions; assisting in one's own decisions; having a say over what happens in the work environment (p. 307). However, the expansion of ICT in several occupations has also increased the opportunity for many workers to choose when and where they do their jobs.

[5] These 146 empirical evidence-based studies were analysed in two systematic reviews. One by Margot Van der Doef and Stan Maes (1999) with 63 empirical studies between 1979 and 1997, focused on corroborating the initial approach of Karasek (1979), which emphasised job demands and control. Subsequently, another review by Jan Häusser et al. (2010) evaluated 83 studies between 1998 and 2007, in which the majority already contemplated social support.

ii) "Intellectual (or skill) ***discretion***", conceptualised both as the degree to which the job generates a cognitive challenge (Karasek, 1979) or as the opportunity for the worker to put their skills into practice to cope with job demands (Häusser et al., 2010).

Related to this specific factor, in his pioneering research, Karasek (1979) used as variables, specifically, if the job requires a high skill level of qualification, if it might be necessary to learn new things, if it is non-repetitious work, or if creativity is required.

- ***Support*** corresponds to the social capital or interpersonal relationships at work that are available to face job demands.

  Initially, the model highlighted "social support related to work" (Johnson & Hall, 1988), both inside and outside the workplace, identifying measures as the interaction with other colleagues or other people and clients during work; or talking during breaks; but also meeting coworkers outside. However, more recently emphasis has been placed on "social support in the workplace", both from colleagues and supervisors or managers, understood it from a instrumental perspective, conceptualised as «the extent to which relationships at work are valuable to the employee in terms of acquiring task information or assistance», although social companionship beyond work environment could be still relevant (Fila, 2016, p. 18).

Second, the Effort-Reward Imbalance (ERI) model explicitly refers to different measures of the two main psychosocial factors included in it[6], being defined as:

- ***Effort at work*** is an «extrinsic demand to which the working person responds, as well as a subjective motivation to match the demand» (Siegrist, 2017: p. 26). Therefore, efforts are shown as job demands or obligations that the contractual employment relationship implies for the worker.

  Specific measures for this factor were developed and validated by Siegrist, Li, and Montano (2014), highlighting the psychometric properties of the Effort-Reward Imbalance (ERI) Questionnaire. In its long version[7], efforts are related to: constant time pressure due to a

[6] Even "over-commitment" or "dependency" on the labour market are essential circumstances for Siegrist (2017), in a pure OSH perspective, it should be conceptualised as contextual or individual moderators (see *Figure 5* again), because both neither are psychosocial factor (result of the organisation and social relationships in the work environment), being "over-commitment" a pattern of motivation or tendency to behave, namely, a personality trait or individual factor, and "dependency" a labour contextual factor that not depends on the enterprise which applies ALMA itself.

[7] Identified and included in the ERI questionnaire in their Table 5 (Siegrist, Li & Montano, 2014, p. 6)

heavy workload; many interruptions and disturbances; a lot of responsibility; being pressured to work overtime; a job physically demanding; the job has become more and more demanding over the past years[8].

- ***Rewards*** are the gains in return for the job efforts.

  As Siegrist (2017) differentiates, there are three types of rewards: «salary or wage (financial reward), career promotion or job security (status-related reward), and esteem or recognition (socioemotional reward)» (p. 25). Therefore, measures of rewards are related to the salary or wage, which would be adequate for the perceived efforts, but it would also be necessary to consider, in return, appropriate job promotion prospects, or to receive the respect and prestige the worker believes they deserve at work, from superiors or colleagues. Other measures of rewards are experiencing adequate support in difficult situations or considering that the occupational position adequately reflects the worker´s education and training (Siegrist, Li & Montano, 2014, p. 6)[9].

The ERI model rewards measures show again that the same factor can influence both positive (motivation, engagement, or satisfaction) and negative outcomes (health problems and safety incidents, or accidents), way as the DCS model does, or some well-being perspectives highlight. The ERI model, for example, considers social recognition or esteem as a reward, which can be boosted by social support (in the terms used in the DCS model). Namely, factors that are present in the organisations at appropriate levels would lead to better results by increasing workers´ motivation and engagement, and therefore, their well-being. But on the other hand, inadequate levels can create OSH risks, mainly psychosocial risks, such as stress.

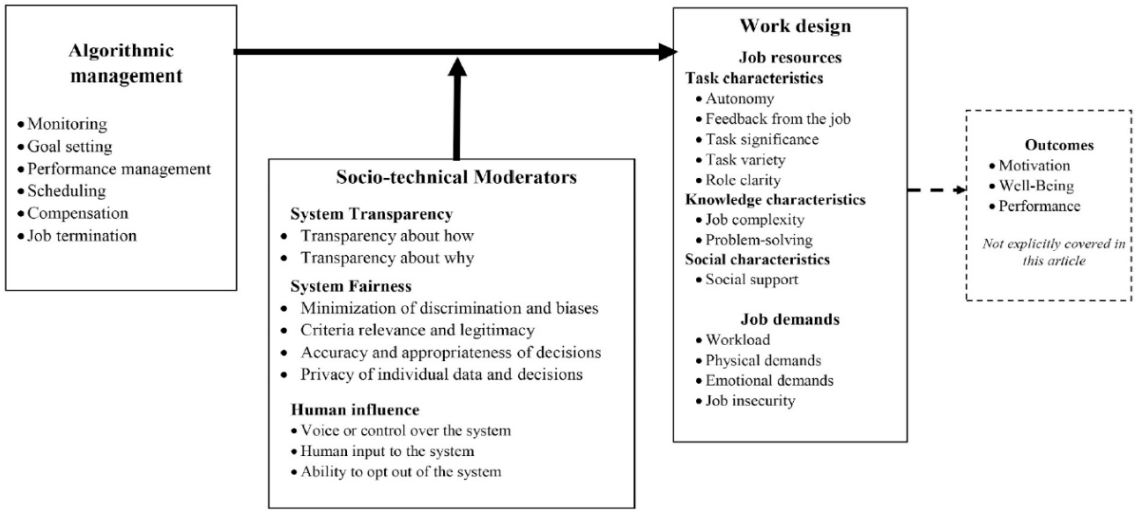
[8] It is essential to highlight that, as shown previously in the final comprehensive approach (*Figure 5*), the job "efforts" in the ERI model are almost the same as the job "demands" in the DCS model. Moreover, their proposed measures are equivalent to the "job demands" of the framework that Parent-Rocheleau and Parker (2022) used to explain the effects of algorithmic management in work design, using the Job Demand-Resources (JD-R) model.

[9] Regarding these two mentioned measures of rewards in the ERI model, one corresponds exactly (experience support in difficult situations) to the social support factor of the DCS model, and the other is related to the intellectual or skill discretion dimension of the control over work factor of the DCS model (that is conceptualised in that model as the opportunity of applying skill or knowledge in the job position).

Similarly, as some authors highlight, the complexity of tasks can be perceived as a motivational cognitive challenge, being a reward, but at the same time, for other workers with different experiences, as an additional effort or higher job demand (De Jonge et al., 2010)[10].

Regarding the comprehensive model of the ALMA-AI project, it is necessary to highlight that Parent-Rocheleau and Parker (2022) framework, a nuclear reference for it, defines job resources as those aspects of work that help workers to achieve their goals and deal with job demands, based on the initial conceptualisation of the JD-R model (Demerouti et al., 2001). Moreover, Parent-Rocheleau and Parker (2022) categorised resources using a theoretical approach to work design, which divides them into task, knowledge, and social characteristics. As *Figure 9* shows, they identify different working characteristics in each of these categories, including job resources as autonomy, job complexity, or social support, which are the most corroborated psychosocial risk factors that can create OSH risks when inappropriate levels appear, generating stress or burnout. For this reason, it was decided to categorise into the ALMA-AI comprehensive model or approach, using the main concepts described above, whose importance has been corroborated by the DCS and ERI models' research (see *Figure 10* compared with *Figure 9*).

Figure 9. Conceptual model of how algorithmic management influences the design of jobs



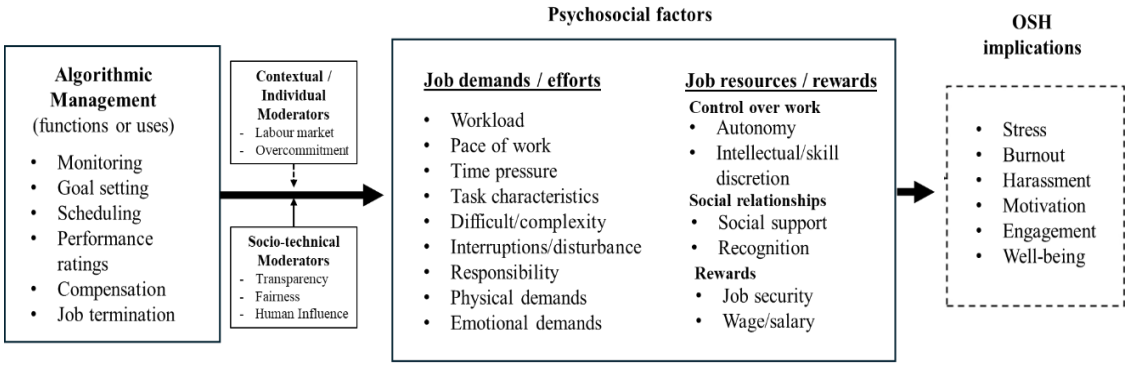
Source: Parent-Rocheleau and Parker (2022, p.2)

[10] However, as the final ALMA-AI project approach summarised (*Figure 5*), this kind of perceptions (e.g. complexity perceived as a challenge or a threat) could be considered as a "individual" moderator factor (personal preferences or traits, such as the Siegrist previously mentioned "over-commitment") which is important to remark are not psychosocial factors *per se*, as neither are contextual ones, or other socio-technical factors identified by Parent-Rocheleau and Parker (2022).

On the other hand, Parent-Rocheleau and Parker (2022, p. 4) also defined job demands, quoted the adjusted JD-R model, as «those physical, psychological, social, or organisational aspects of the job that require sustained physical and/or psychological (cognitive and emotional) effort or skills and are therefore associated with certain physiological and/or psychological costs» (Bakker & Demerouti, 2007, p. 312). Additionally, as the main job demands in their framework, Parent-Rocheleau and Parker (2022) highlight specifically four: workload, physical demands, emotional demands, and job insecurity, being the first three ones the same that Karasek (1979) identified as demands in the DCS model in his first conceptualisation, and the forth consider by Siegrist (1996, 2017) as a reward in its opposite side (job security). Moreover, Parent-Rocheleau and Parker (2022) include all these four (psychosocial) factors, because they are based «on the early evidence regarding the effects of AM on job demands» (p. 4).

However, in order not to lose sight of any potential job demand/effort or resources/rewards studied, the ALMA-AI project's approach includes all the factors of the DCS, ERI, and JD-R models previously described (see *Figure 10*, which is also part of *Figure 5*). Additionally, it is important to note that, although Parent-Rocheleau and Parker (2022) describe socio-technical moderators (see *section 2.1*), for the purpose of the project, it was decided the scientific literature review was focused on the evidence-based articles or publications that corroborated the relationship between ALMA (also specific functions or uses) and psychosocial factors, ideally if OSH implications are included. Therefore, although socio-technical (e.g., transparency, fairness or human influence), contextual (e.g., dependency on the labour market), or individual (e.g., overcommitment) moderators could be highlighted, if they were not part of that association or framed it, they were dismissed in the analysis.

Figure 10. Conceptual approach of how algorithmic management determines OSH implications



Source: Own elaboration based on Parent-Rocheleau & Parker (2022, p.2) and other models

III. OCCUPATIONAL SAFETY AND HEALTH (OSH) IMPLICATIONS & CONCERNS

3.1. ALMA in Europe: Origins in "platform work" and emergence in regular work

Karolina Pawłowska, Joanna Kamińska & Katarzyna Hildt (CIOP-PIB, Poland)

Algorithmic or data-driven management is not a marginal phenomenon, limited to specific digital labour platforms, but is gradually spreading to traditional workplaces. Several technologies that enable algorithmic management are widespread in the EU, particularly in some Member States and large companies. The EUROSTAT dataset shows that the most widespread technologies enabling data-driven management are enterprise resource planning (ERP), reaching 43.3 % in 2023, and customer relationship management (CRM) software, which stood at 25.8 % in 2023[11]. Other technologies are relatively less common: for example, 15.3 % of enterprises reported using Business Intelligence software in 2023 (a lower ratio compared to ERP and CRM), or Artificial Intelligence (AI), that although increasing is present in around 13.5% of EU enterprises with 10 or more employees in 2024, being lesser the proportion that are using AI to automate workflows or assist in decision making (uses more related to algorithmic management), only 4.2% of the EU enterprises in 2024. However, the differences are remarkable depending on the size of the company, reaching the use of some application of AI 41.2% in large EU enterprises, but only 11.2% in small ones[12]. Such technologies can mainly affect management functions of controlling, directing, and guiding, by facilitating the monitoring of employees, but also can enable semi-automatic task allocation or setting the content or pace of work.

As previously mentioned, the use of AI and algorithmic management in various organisations is growing, but the available data on this subject is not yet robust, which makes it difficult to indicate how many enterprises or institutions are currently applying them. According to data from McKinsey research in 2019, approximately 58% of the 2,395 companies surveyed worldwide implemented AI in at least one area of the enterprise. Similarly, HR leaders, managers, and employees surveyed by Oracle in 10 countries indicated that they used AI in their daily work. In turn, academic experts in the field of AI indicate that despite obtaining high statistics in these studies on the use of AI in enterprises, in reality, many organisations use simple algorithms and confuse them with AI (Christenko, Jankauskaitė & Paliokaitė, 2022).

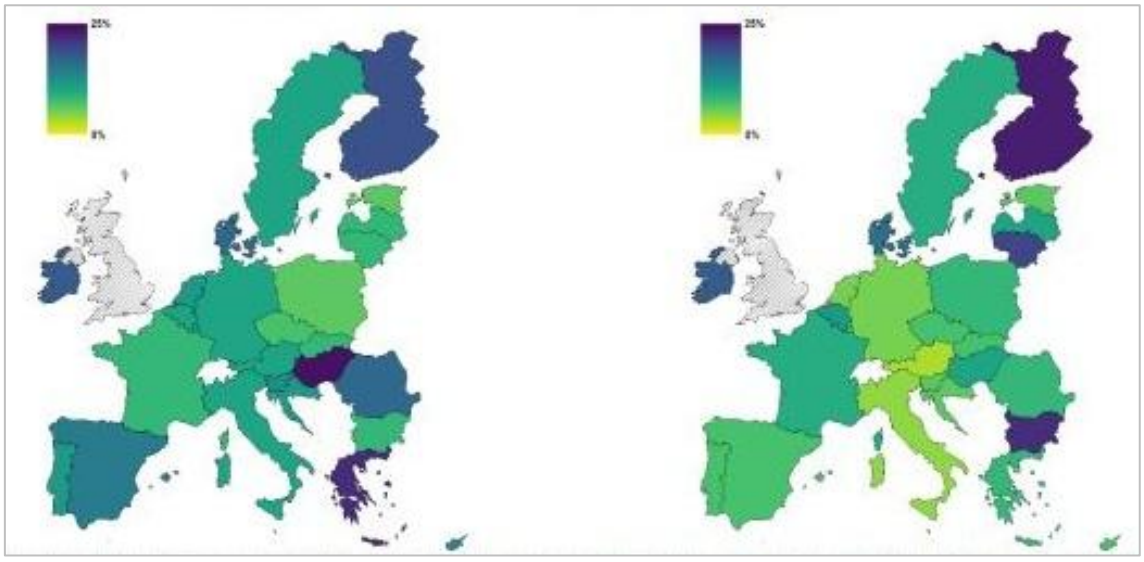
[11] See EUROSTAT "E-Business integration – Highlights" in this link

[12] EUROSTAT "Digital economy and society statistics – Highlights / Artificial Intelligence (AI)" in this link

One of the first estimations of the prevalence of ALMA, although indirect, was the result of two questions included in the third *European Survey of Enterprises on New and Emerging Risks 2019* (ESENER-3) conducted by EU-OSHA. As Aleksandr Christenko et al. (2022a) pointed out, one approach to estimate the ALMA prevalence around Europe was the mapping of the usage of technologies that are more associated with worker management. As *Figure 11* shows, on the one hand, the ESENER-3 survey asked managers if their companies "use machines, systems or computers **determining the content or pace of work**" (left map in *Figure 11*), which on average was **15% of the European enterprises in 2019**, considering the ESENER-3 dataset shown in Annex III of the EU-OSHA report (Christenko et al., 2022a). On the other hand, it asked about "use machines, systems or computers **monitoring workers´ performance**" (right map in *Figure 11*), which was present **in 11.4% of enterprises on average** in Europe only six years ago.

As Christenko et al. (2022a) also highlight, although several experts consider that AI for worker management first became widespread in mature economies and was then adopted by following them, the ESENER-3 survey dataset about the mentioned questions points out that there is no clear geographical pattern to this extent and the usage of digital technologies for worker management is present in different countries around Europe and differs also by the type of usage, determine work or monitor workers, although no country exceeded 25% (*Figure 11*).

Figure 11. Percentage of workplaces that use digital technologies to determine the content or pace of work (left) or to monitor workers´ performance in Europe in 2019

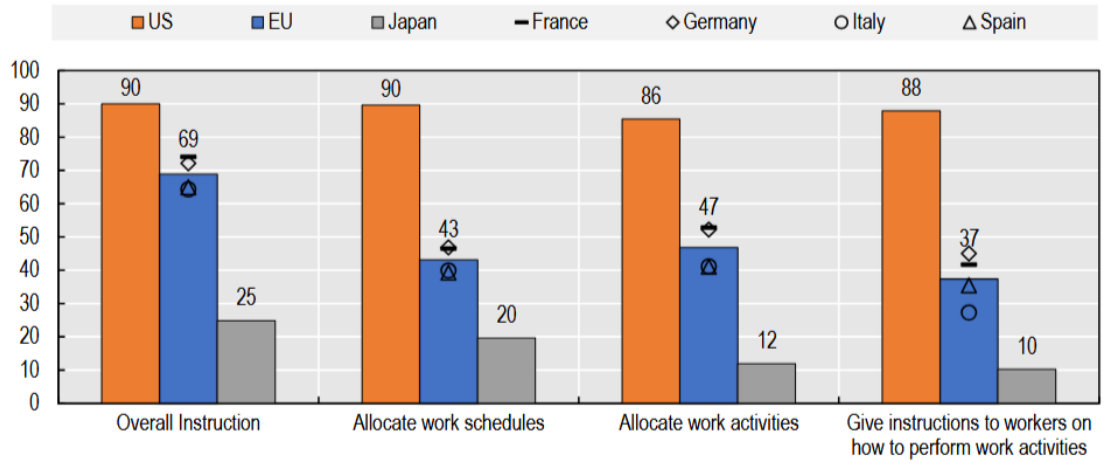


Source: Christenko et al. (2022a, p.26)

However, the recent report of the OECD published in February 2025, showing the results of a survey of 6.047 managers in six countries (USA, Japan, France, Germany, Italy and Spain) concludes that "**algorithmic management is already widespread**" today, highlighting that «74% indicate that their firms use at least one tool to instruct, monitor or evaluate employees – more than previously understood» (Milanez, Lemmens & Ruggiu, 2025, p. 18).

The OECD survey also verifies that there are different types of ALMA tools that companies are using nowadays and, as it is arguing, that can produce different outcomes in terms of the levels of risk to employees, being monitoring tools may be more likely to collect personal data in the way they are designed (compared to instructional tools), while employee evaluation tools may be more likely to be biased (compared to both instructional and monitoring tools). However, what is clear is the variance in the use of ALMA between countries and the types of tools applied. The results of the OECD survey show that US companies are heavy users of all types of tools, even those used for evaluation (e.g., setting goals for employees and rewarding or penalizing poor performance). European companies, on the other hand, tend to adopt tools that are less potentially intrusive to employees (i.e., less likely to collect sensitive data), such as instructional tools and basic monitoring tools. While Japanese companies are moderate users of ALMA tools, they tend to adopt the most widespread monitoring tools (Milanez et al., 2025).

Figure 12. ALMA instructions tools (goal setting and scheduling) prevalence in OECD countries

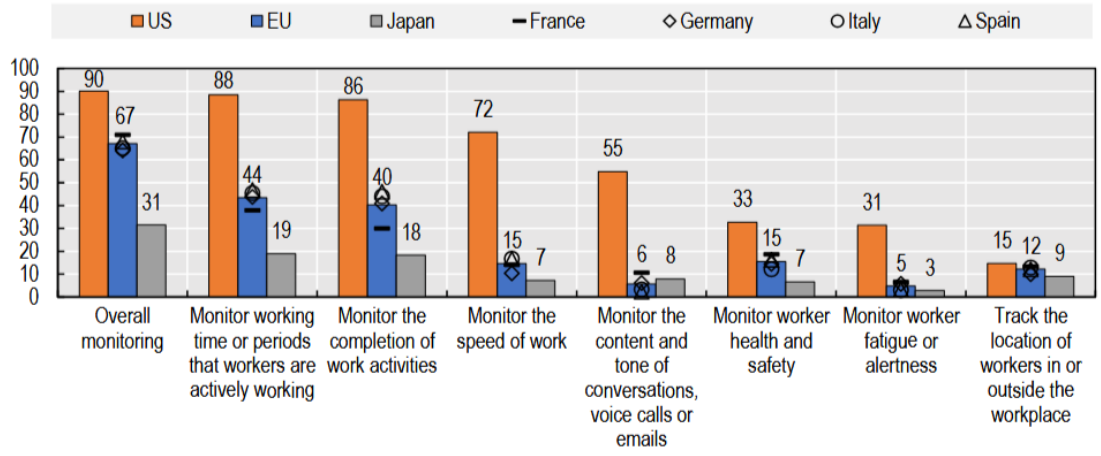


Source: Milanez, Lemmens & Ruggiu (2025, p. 24)

As *Figure 12* visualises above, in American and European companies, employee **instruction** tools are the most widespread (which are equivalent to the "goal setting" and "scheduling" ALMA functions categorised in *section 2.1* and in the ALMA-AI project approach in *Figure 5*). About 90% of companies in the US report adopting at least an ALMA tool for instruction. Furthermore, most companies use these tools to assign work schedules ("scheduling") and work activities, and to give employees instructions on how to perform work activities ("goal setting"). In European countries, 69% of companies report adopting such tools for at least one of these functions. However, the percentage of companies is lower in the different ALMA uses, from 37% for giving employees instructions on how to perform activities to 47% for assigning work activities on average, being also differences between European countries, although not great ones, from a more prevalent use of ALMA to goal setting and scheduling in France and Germany to a lesser application of the mentioned ALMA tools in Spain and Italy (see also *Figure 12*).

Likewise, monitoring tools are widely used in the United States, moderately in European countries, and less frequently in Japan: 90%, 67%, and 31% of companies, respectively, use them to automate at least one monitoring task (see below *Figure 13*). Although there are significant differences in the levels of adoption across regions, a similar pattern is observed across all regions. The use of monitoring tools is more common for "basic" monitoring activities, such as monitoring work time and work performance.

Figure 13. ALMA monitoring tools prevalence in OECD countries

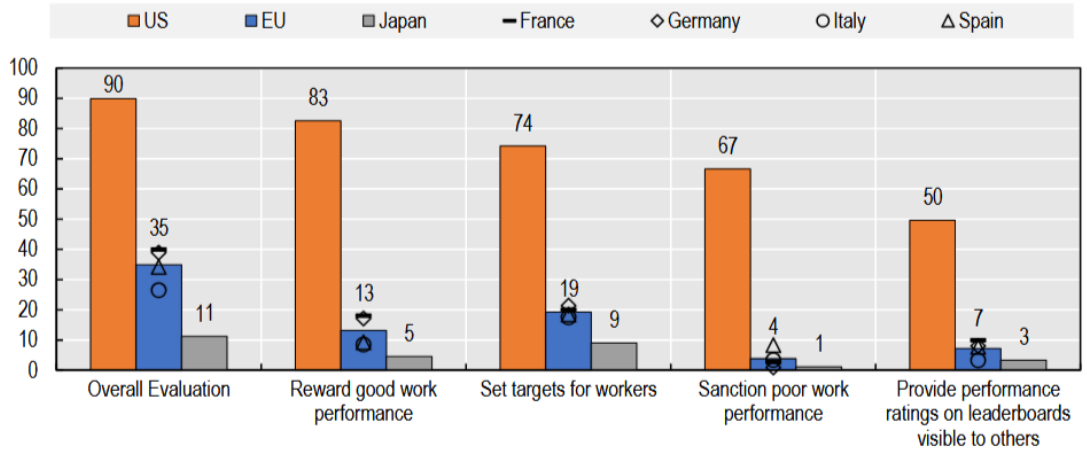


Source: Milanez, Lemmens & Ruggiu (2025, p. 25)

As noted above, such use cases may involve data collection without algorithmic data processing but are included based on the assumption that employee **monitoring** is a management function. Software is used for monitoring work time by 88% of US companies, 44% of European companies, and 19% of Japanese companies. It is used for monitoring work performance by 86% of US companies, 40% of European companies, and 18% of Japanese companies (see *Figure 13*). It is worth noting that 72% of American companies use software to monitor work speed, while in Europe (15%) and Japan (7%), these percentages are much lower. Importantly for it potential benefit for OSH, the OECD survey shows that a third of US companies use ALMA tools for monitoring the health and safety of workers, being less than the percentage in European countries, only 15% on average, with also important differences in the ALMA use for monitoring fatigue or alertness (31% in US companies and only 5% in European countries).

Furthermore, there are striking differences in the prevalence of **assessment tools** across regions (see *Figure 14*). In the United States, 90% of companies use an algorithmic management tool to partially or completely automate at least one assessment task. The same percentage drops to 35% in European countries and 11% in Japan. In the United States, 83% of companies use such software to reward good performance, 74% to set goals for employees, 67% to penalise poor performance (i.e., disciplinary action or withholding of rewards such as training opportunities), and 50% to provide performance ratings in leaderboards visible to others.

Figure 14. ALMA evaluation (performance and compensation) prevalence in OECD countries



Source: Milanez, Lemmens & Ruggiu (2025, p. 25)

The abovementioned shares in US companies of ALMA tools to evaluate workers' performance and to establish compensation rewards or penalties are significantly higher than those observed in the other two regions. In European countries, only 13% of companies use such software to reward good performance ("compensation" function in ALMA-AI project model), 19% to set goals for employees (specific use more related to "goal setting" function), 4% to penalise poor performance, and 7% to provide ratings in leaderboards (part of the "performance ratings" ALMA function). On the other hand, in Japan, 5% of companies use software to reward good performance, 9% to set goals for employees, only 1% to punish poor performance, and 3% to provide ratings on scoreboards. Assessment tools are also risky because they can result in actions that have consequences for employees' livelihoods, such as recommendations for promotion or dismissal. Furthermore, to the extent that assessment tools are trained on historical data that reflects past performance in a company, they can embed and perpetuate biases if not carefully implemented (Milanez, Lemmens & Ruggiu, 2025).

In summary, the OECD recent survey shows that in Europe between 65% and 70% of companies use at least one tool for ALMA functions associated with "monitoring" or instruction purposes ("goal setting" or "scheduling") and around a third of European companies use ALMA for worker evaluation ("performance rating" or "compensation", including reward and sanction). However, the most used specific tools do not exceed half of the European companies for any purposes, not for goal setting or scheduling functions (allocate work activities are used by 47%, allocate schedules by 43%, and give instructions on how to perform work by 37%), nor for monitoring purposes (44% working times or 40% the completion of work activities) and especially neither for evaluation (only 19% to set targets or 13% to reward good work performance). Therefore, although ALMA is expanding nowadays, at least half of European enterprises do not use it yet, and it seems the most commonly used tools for ALMA are for general objectives and not invasive to workers, yet (allocation and monitoring of general work activities or schedules). Another important finding is that the use of ALMA is widespread in the USA, potentially boosting risks for the workers, but also creating opportunities for OSH, for example, with the monitoring of health and safety or fatigue and alertness, which are purposes that could increase the protection of the workers safety and health at work, if they are properly managed and personal data privacy and non-discrimination issues (data bias) are assured.

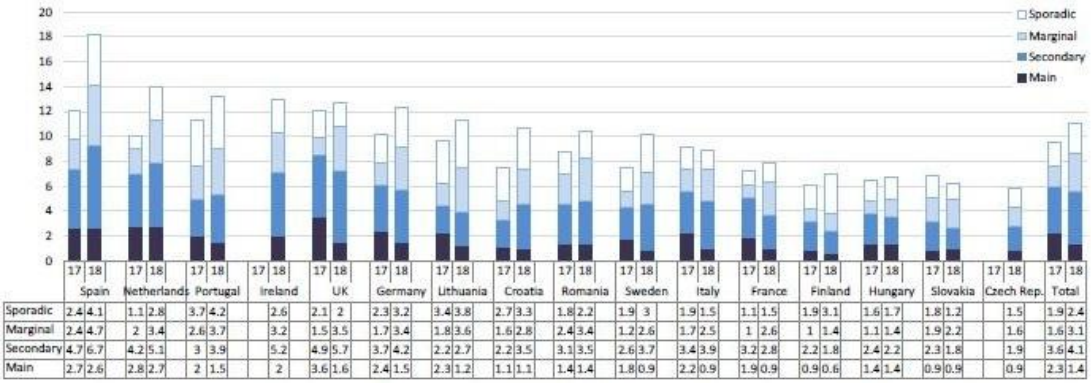
Platform work in the origins of ALMA

Platform work, which has used ALMA from its very beginning, is nowadays on the rise. Digital platforms are playing an increasingly important role in the global economy, disrupting traditional sectors such as transportation and services. However, the impact of these changes on the labor market is twofold: for some, this may mean greater flexibility and earning opportunities, while for others, it may mean job instability and uncertainty. Digital platforms such as Uber, Deliveroo, and TaskRabbit are becoming more common in the labor market, disrupting traditional employment models. Platform workers act based on short-term contracts, often on their own, and frequently have very different experiences. Some value the flexibility that platform work offers, while others struggle with instability and a lack of social security. Many people see platform work as a temporary, transitory form of employment until they find better working conditions. This type of work is seen as a way to earn money quickly, not long-term employment (Fernández-Macías et al., 2023).

Platform work is not always well-regulated. Many people do not have access to traditional social benefits, such as health insurance or pensions. There is a need for new regulations that take into account the specificities of platform work. Although work on digital platforms offers some flexibility, wages are often unstable, and working conditions can be unfavorable, especially in the absence of adequate social protections. Some studies indicate that the average earnings of platform workers are lower than in traditional forms of employment. There is, therefore, a need for better regulation of this sector to ensure fairness and security for platform workers, especially in terms of social protection and job stability (Fernández-Macías et al., 2023).

Beyond the most recent dataset gathered by the OECD, a cutting-edge survey about ALMA, highly referenced by other institutions, was conducted by the JRC of the European Commission, the *Algorithmic Management and Platform Work* (AMPWork) survey, which was a first estimation of the prevalence of ALMA with representative samples in Spain and Germany (Fernández-Macías et al., 2023). However, the first datasets gathered by the JRC were pilot studies to estimate the volume of platform work in Europe, which was also one of the first datasets that included ALMA-related questions. As *Figure 15* visualises, the previous COLLEEM surveys allowed to estimate the percentage of platform work, ranging between the intensity of hours and incomes, calculating that around **1.4% and 2.3%** of workers had **platform work as their main job** in the 2017-2018 period in Europe (Urzi, Pesole & Fernández-Macías, 2020).

Figure 15. Prevalence of platform work and its types in the period 2017-2018 around Europe



	Spain		Netherlands		Portugal		Ireland		UK		Germany		Lithuania		Croatia		Romania		Sweden		Italy		France		Finland		Hungary		Slovakia		Czech Rep.		Total	
	17	18	17	18	17	18	17	18	17	18	17	18	17	18	17	18	17	18	17	18	17	18	17	18	17	18	17	18	17	18	17	18	17	18
Sporadic	2.4	4.1	1.1	2.8	3.7	4.2		2.6	2.1	2	2.3	3.2	3.4	3.8	2.7	3.3	1.8	2.2	1.9	3	1.9	1.5	1.1	1.5	1.9	3.1	1.6	1.7	1.8	1.2	1.5		1.9	2.4
Marginal	2.4	4.7	2	3.4	2.6	3.7		3.2	1.5	3.5	1.7	3.4	1.8	3.6	1.6	2.8	2.4	3.4	1.2	2.6	1.7	2.5	1	2.6	1	1.4	1.1	1.4	1.9	2.2	1.6		1.6	3.1
Secondary	4.7	6.7	4.2	5.1	3	3.9		5.2	4.9	5.7	3.7	4.2	2.2	2.7	2.2	3.5	3.1	3.5	2.6	3.7	3.4	3.9	3.2	2.8	2.2	1.8	2.4	2.2	2.3	1.8	1.9		3.6	4.1
Main	2.7	2.6	2.8	2.7	2	1.5		2	3.6	1.6	2.4	1.5	2.3	1.2	1.1	1.1	1.4	1.4	1.8	0.9	2.2	0.9	1.9	0.9	0.9	0.6	1.4	1.4	0.9	0.9	0.9		2.3	1.4

Source: Urzi, Pesole & Fernández-Macías (2020, p. 16)

Subsequently, in the in-person survey carried out by JRC in 2022, the AMPWork survey, shows similar percentages related to the platform work as a main job, especially in Spanish sample, in which was calculating 1.4% of the wokforce were platform workers, as platform work is their main job (although in Germany it differed, as it was only 0.59% of the german labour market).

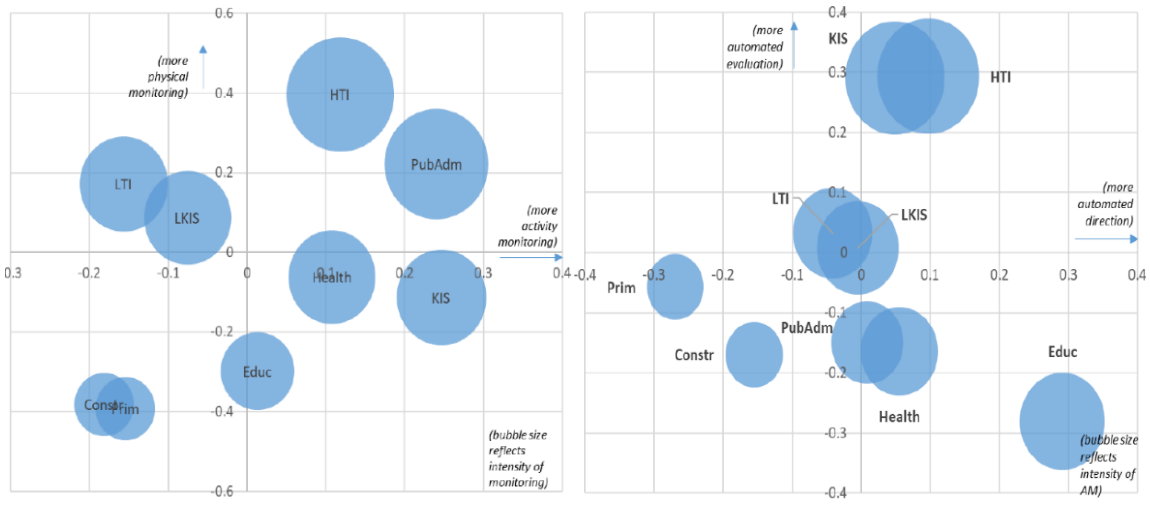
However, the most important contributions of the COLEEM and AMPWork surveys conducted by the JRC of the European Commission concerning the ALMA-AI project were that they included questions about the prevalence of ALMA and additionally about characteristics of the workers and their working conditions when they are managed by algorithms or AI. Moreover, the AMPWork survey also allows a classification of workers according to levels of platformisation, defined as the use of digital devices for digital monitoring and algorithmic management at work. Around 10% of German workers and 18% of Spanish workers are "**soft platformised**", to some extent, with 1.3% and 6.1%, respectively, being "**strongly platformised**." Then there is a much larger category of workers (50.6% in Germany, 41.3% in Spain) who use digital tools at work but who are neither subject to digital monitoring nor algorithmic management systems. Higher percentages of platformised workers are found among **clerks and operators**, in **High-Tech Industries** (HTI), **Knowledge-Intensive Services** (KIS) and **Public Administration** (between 10% and 30% of soft plus strongly platformised workers), although those more organised or monitored by algorithms or AI are professionals and clerks, and in HTI and KIS sectors (around 10% of strongly platformised workers in all these categories). ALMA is also often found in people working outside the regular premises of the employer (at home, in a vehicle, or in public spaces). These types of highly organised by ALMA jobs are often associated with more detailed work and complex procedures, but also with greater monotony and stress (Fernández-Macías et al., 2023).

ALMA prevalence in various sectors of the economy

According to data obtained by in-depth interviews with experts in the field of AI, algorithm-based management most often concerns those sectors of the economy that are based on manual, routine, or physical activities. In this context, **logistics, manufacturing, transport, and healthcare** are mentioned. In turn, literature data also indicate that such systems are common in the case of lower-skilled white-collar workers (e.g., call centers, whose work is also routine). ESENER-3 data also indicate that more frequent use of technologies enabling ALMA is used by sectors related to performing manual work (agriculture, mining, production, quarries). Such systems are also used much more often by enterprises in the manufacturing sector compared to enterprises in the information and communication sector or financial and insurance activities. Such systems are used more often by large enterprises that are part of the private sector (Christenko, Jankauskaitė & Paliokaitė, 2022).

Regarding economic sectors, the AMPWork survey also shows those in which different uses of ALMA are more prevalent. On the one hand, monitoring was divided by "physical" (CCTV and webcams, tracking workplaces, entry or exit, and working times) or "activity" monitoring (computer use, voice calls, emails, or internet use). As *Figure 16* (left) visualises, both types of monitoring are more prevalent in the High Technology Industry (HTI) and **Public Administration**, while the less monitored sectors are Construction and the primary sector.

Figure 16. Digital monitoring (left) and other algorithmic management uses (right) by sector



Source: Fernández-Macías et al. (2023, p. 25, 33)

On the other hand, the AMPWork survey in Spain and Germany shows a prevalence of other ALMA uses in some sectors, divided between those related to the automated direction uses (instructions or automatic allocation of time/shifts activities, or speed of work) and evaluation (performance publicly ranked, badges for performance, or ratings to allocate or cancel work). As *Figure 16* (right) shows, the sector in which automated direction is more likely is **Education**, despite it being the one with the least likelihood of automated evaluation. On the contrary, **High Technology Industry** (HTI) and **Knowledge Intensive Services** (KIS) are those in which evaluation is more present, although direction is not important.

However, the differences between sectors are statistically insignificant when differences between countries are also taken into account. The lack of significant differences in the prevalence of algorithmic management across sectors contrasts with evidence in specific countries, such as the United Kingdom, in which the use of AI varies across sectors (Calvino et al., 2022), although, as discussed, algorithmic management tools are not necessarily AI-based.

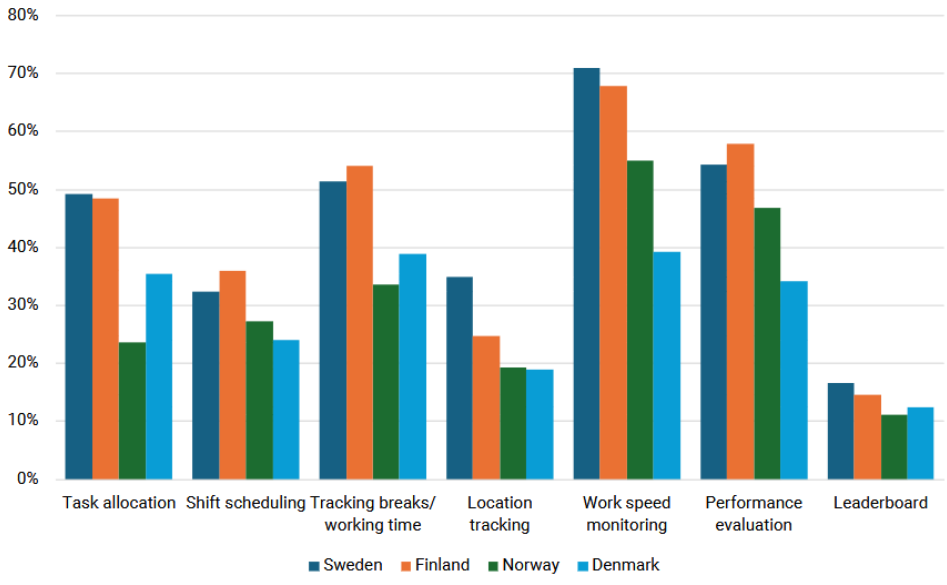
Regarding **occupations**, the AMPWork survey shows that industrial and machine **operators** are those with the highest levels of both automated direction and physical monitoring, while **managers** are more prone to be automated evaluated by ALMA tools, and **clerks and professionals** are those who experienced more activity monitoring (Fernández-Macías et al., 2023). Additionally, the survey identifies the **types of tasks** that are more automated by ALMA (including monitoring), being the most well-known **platform work services** (delivery and taxi), in which it is more widespread. Nevertheless, other tasks in which ALMA is more prevalent are some **non-professional "microtasks"**, such as online sales and marketing, but also content **moderation**, despite of some **online professional tasks** are also more likely to be coordinated, monitored or evaluated by ALMA, especially the online creative and multimedia work tasks (Fernández-Macías et al., 2023).

In terms of firm size, the use of **ALMA tools is somewhat higher among larger firms** across all tool categories. This is expected because larger firms may be more able to make large investments in new technological systems and because larger firms have more employees to coordinate. However, the OECD survey shows that the difference is small: 76% of managers in firms with 250 or more employees use such tools, compared to 74% of managers in medium-sized (50–249 employees) and small (20–49 employees) firms. This may be because the study excluded firms with fewer than 20 employees, as the prevalence of algorithmic management is

likely to be even lower in very small firms. Finally, in terms of the number of employees for whom managers are responsible, there are no significant differences in adoption between companies where managers are responsible for a small number of employees (less than 5) compared to a larger number (more than 20) (Milanez, Lemmens & Ruggiu, 2025).

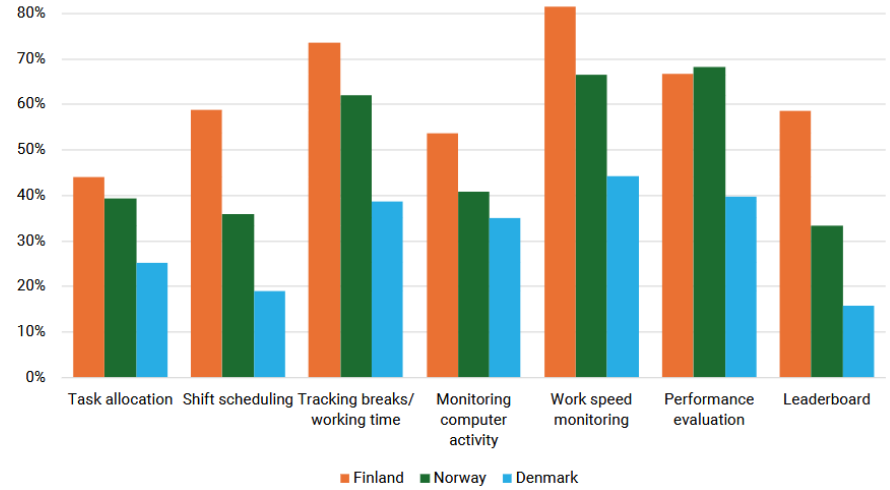
Nevertheless, research conducted in Denmark, Finland, Norway and Sweden on 6,769 respondents indicates that the use of ALMA is quite high among employees in the **warehouse, customer service/telemarketing, citizen service, retail, office, aviation and financial sectors**: 3 out of 4 respondents indicate that at least one form of such management is used in their company (Jensen et al., 2024). Algorithmic task allocation is most common in the warehouse sector (see *Figure 17*). Aviation is also indicated as a sector in which algorithmic task allocation is widespread. Automatic tracking of employee work by computer is widely used in Denmark, Finland, Norway, and Sweden in the customer service/telemarketing and warehouse sectors (*Figure 17* and *Figure 18*). The question about location tracking was asked only in the warehouse and retail sectors and is more common in the warehouse sector (*Figure 17*). The relatively most common form of algorithmic management is monitoring computer activity. This form is quite common in all sectors studied (Jensen et al., 2024). Monitoring the speed of work using computer programs or digital systems is more often indicated by employees in the warehouse and customer service/telemarketing sectors (*Figure 17* and *Figure 18*).

Figure 17. Proportion of warehouse workers experiencing each form of ALMA



Source: Jensen et al. (2024, p. 31)

Figure 18. Proportion of customer service/marketing workers experiencing each form of ALMA



Source: Jensen et al. (2024, p. 32)

Assessment of work quality using a computer is common in customer service/telemarketing and warehousing, but also in aviation (Jensen et al., 2024). In turn, displaying work results on a board or screen in order to compare them with the results of other employees is most commonly used in the customer service/telemarketing sector (*Figure 18*).

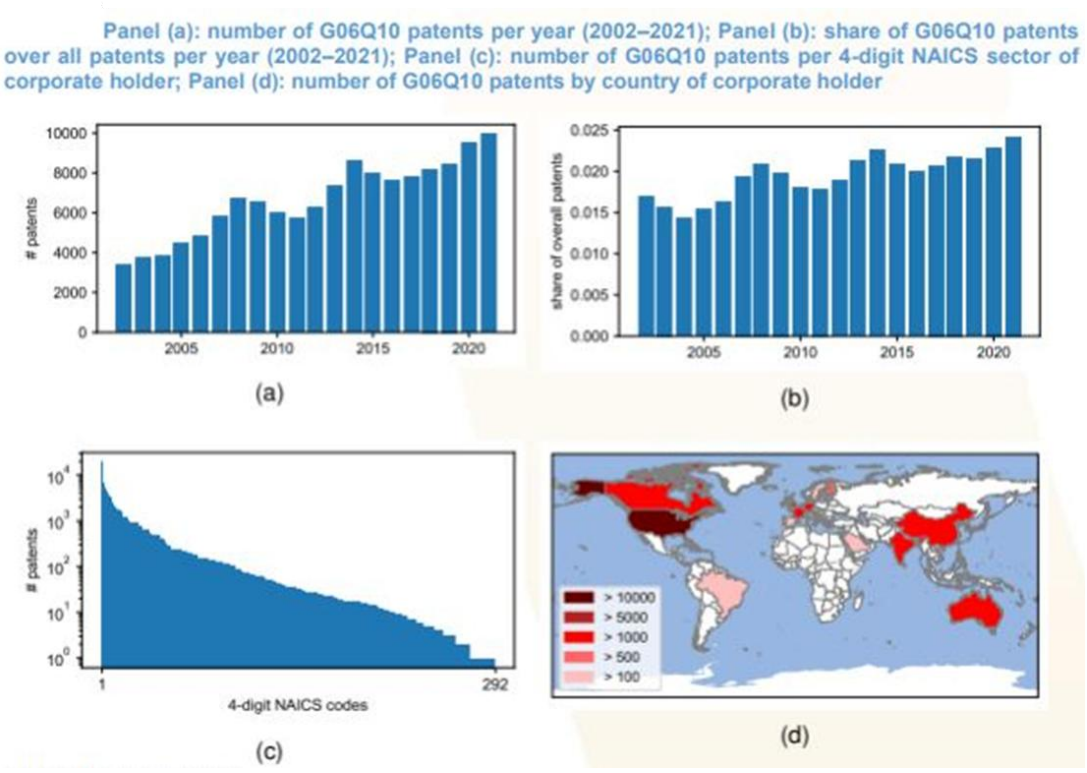
A comparison in terms of algorithmic management between the countries participating in the study is only possible in the warehouse and customer service/telemarketing sectors, which are represented, respectively, in the countries studied. Looking first at warehouse employees, we can observe that such employees in Sweden and Finland experience algorithmic management more than employees in Norway and Denmark (*Figure 17*). When it comes to customer service/telemarketing employees, the highest percentage of those experiencing algorithmic management was noted among employees from Finland (*Figure 18*).

Patents as another indicator of ALMA prevalence

Considering the number of patent applications in the CPC subclass "Data processing systems or methods", which are understood as technologies related to algorithmic management, it should be noted that the number of such applications has been gradually growing, from approximately 4,000 in 2005 to around 10,000 in 2020 – as Panel (a) and Panel (b) visualise in *Figure 19* – being a continuous increase in the last two decades. This expansion indicates that entities are interested in patenting solutions related to ALMA.

Notably, as their authors pointed out, «the majority of the retrieved **patents predominantly focus on** scopes of application aimed at **enhancing efficiency and improving decision-making processes»,** instead of being designed to improve OSH (Staccioli & Virgillito, 2024, p. 14). The dominant sectors (of a total of 292 sectors analysed) are "Design of computer systems and related services" with 18,762 patents, "Deposit credit brokerage" with 6,191 patents and "Production and reproduction of magnetic and optical media" with 5,119 patents (Staccioli & Virgillito, 2024). In turn, taking into account the world regions – as Panel (d) shows in *Figure 19* – the western region of the USA (86,301 patents), Germany (4,572), and Canada (3,416) dominate. In the Eastern region, Japan (9792), South Korea (2233), China (1968), India (1465) and Taiwan (939) have a significant share of patents. In addition, Brazil and Saudi Arabia have more than 100 patents to their credit. These numbers are the result of basic patenting activity at the firm level (Staccioli & Virgillito, 2024), representing another approach to identify the prevalence of ALMA in different sectors and countries beyond the more common estimations based on surveys of workers or managers.

Figure 19. Evolution of the number of patents related to ALMA and geographical dispersion



Source: Staccioli & Virgillito (2024, p. 6)

3.2. OSH implications and psychosocial risks: Cutting-edge institutions´ analyses

Mairi Bowdler (TNO, The Netherlands) & Marie Jelenko (AUVA, Austria)

This section aims to share an overview of a selection of the grey literature from recognised institutions covering the OSH implications of ALMA on workers. The project partners collected grey literature from various institutions, including EU-OSHA, JRC, and ILO. Additionally, it is important to highlight the results of two recent literature reviews that offer significant insights and findings regarding platform workers.

European Agency for Safety and Health at Work (EU-OSHA)

The initial focus will be on the substantial documentation available from EU-OSHA on this topic within the timeframe of the analysis (2022-2024), including 10 selected publications in the grey literature review (Christenko et al., 2022a, 2022b; Christenko, Jankauskaitė & Paliokaitė, 2022; Reinhold et al., 2022; Pesole, 2023; Pesole & Cetrulo, 2024; Molina et al., 2024; Jankauskaitė et al., 2022; Gillis, 2024; Staccioli & Virgillito, 2024). EU-OSHA refers to ALMA as «worker management system that gathers data, often in real time, on the workspace, workers, the work they do, and the (digital) tools they use for their work, which is then fed into an AI-based model that makes automated or semi-automated decisions or provides information for decision-makers on worker management-related questions» (Reinhold et al., 2022, p. 5).

In one of the reports, EU-OSHA specifically discussed some specific functions of ALMA and AI tools, such as surveillance and monitoring (Pesole, 2023). However, equally to other publications of EU-OSHA, it used general data about ALMA and information from various sources, including:

- EU-OSHA surveys, such as the OSH Pulse 2022 (Pesole, 2023), but also based on the dataset of ESENER-3 (Christenko et al., 2022a).
- Literature review (Reinhold et al., 2022; Molina et al., 2024; Christenko et al., 2022a, 2022b; Gillis, 2024; Staccioli & Virgillito, 2024)
- Case studies (Pesole & Cetrulo, 2024; Molina et al., 2024; Gillis, 2024)

These publications cover varying occupations and sectors, as evident in Chapter 4 of this report. The EU-OSHA is also a cutting-edge institution that delved into both the platform economy and more traditional workplaces, where ALMA and AI are also now present.

In terms of OSH implications, EU-OSHA highlights the various impacts on workers. For example, a report developed by Annarosa Pesole (2023) analyses the data from the OSH Pulse 2022 survey (27,250 workers in Europe), revealing increased psychosocial risks and factors when there is a greater adoption of ICT in the workplace, and when ALMA practices are more present.

In the report "Artificial intelligence for worker management: implications for occupational safety and health" (Reinhold et al., 2022), various risks for workers' safety and health are listed. It begins with a risk factor that is said to be repeatedly observed: '**intensification of work**'; the ALMA systems often intensify work by monitoring and pressuring employees to maximise their productivity. Closely tied to this risk is '**Loss of job control and autonomy'**, which is another risk factor consistently identified throughout the literature observed by EU-OSHA; the systems often reduce job control and autonomy by imposing various aspects of the job, such as pace and content. This leaves workers with lowered decision-making powers, which in effect is linked to the risk of stress and negative mental health outcomes, but also with reduced performance. Further compounding this is **dehumanisation and 'datafication' of workers**, where workers are viewed primarily through the lenses of data and metrics. This report also highlights the psychosocial risks of ALMA. Continuous monitoring and algorithmic evaluation can lead to an environment of surveillance that can have negative consequences, such as **increased anxiety and burnout**. Additionally, with the systems encouraging **social isolation** and erosion of traditional support, the risk of loneliness, depression, and lack of team cohesion is increased.

EU-OSHA also highlights **other ethical and legal risks** that are based on **privacy, discrimination, and power imbalances**. Since these systems collect personal data, this can lead to potential biased decision-making in hiring, promotion, or disciplinary processes. In relation to this, these systems are at risk of **technical malfunctions**, which pose consequences to for example, physical injury, particularly in high-risk environments such as manufacturing. As well as listing all of the potential aforementioned negative OSH implications from ALMA-based systems, the report also highlights that the systems can provide **opportunities for OSH**. The systems can enhance OSH by enabling **real-time monitoring of physical and mental well-being**, which could support tailor-made task allocation, promote worker engagement, and update OSH training through data-driven insights.

Joint Research Centre (JRC) & International Labour Organization (ILO)

Definitions and perspectives

JRC and ILO explain their position on ALMA-AI in their background paper "The Algorithmic Management of work and its implications in different contexts", elaborated by Sara Baiocco and Enrique Fernández-Macías (JRC) and by Uma Rani and Annarosa Pesole (ILO). The paper defines algorithmic management as "the use of computer-programmed procedures for the coordination of labour input in an organisation" (Baiocco et al., 2022) – being the same definition as JRC previously set (see *section 2.1*) – and highlights two key aspects: 1) the algorithm itself as a set of predefined rules that must be followed in sequence to solve a problem, and 2) the management tasks associated with running an organisation in relation to coordinating the deployment of labour (*ibid*, pp. 5-6). The expansion of the capacity to store, process and communicate information through electronic digital devices, cloud services and cloud infrastructure is driving the ongoing deployment phase of algorithmic management. Key technologies such as big data analytics, machine learning and geo-location are contributing to the further proliferation of workforce management using algorithms and AI. As digital technologies expand, companies are increasingly digitising their production processes, making it easier and more efficient to use algorithms to coordinate these processes.

However, the JRC-ILO report emphasises that many key features of algorithmic management are not new: Max Weber's concept of bureaucracy, for example, highlights the great importance of formal rules and impersonality in their application, being thus directly related to algorithmic management. Furthermore, the standardisation and rationalisation of tasks are central to both algorithmic management and the concept of scientific management (Taylorism). The term 'digital Taylorism' refers directly to algorithmic management, as the use of digital devices makes it possible to divide and standardise tasks that were previously considered too complex for this form of work organisation (e.g., many tasks in the service sector).

Algorithmic Management in Regular Workplaces

As the JRC-ILO report points out, the development of algorithmic management has its origins, and is most widespread, in platform work (as pointed out in the previous *section 3.1*), in which digital labour platforms (DLPs) design and deploy a set of algorithms to match suppliers and consumers of specific labour services and coordinate the delivery of those labour services.

Recent studies have shown a rising tendency for the utilisation of algorithmic management outside of DLPs. Nevertheless, this practice still only accounts for a relatively small proportion of total management activities when compared with human management. However, as digitalisation facilitates and fosters the use of algorithmic management, the JRC-ILO report emphasises that its importance is also likely to increase in traditional forms of work. The report also pointed out that the use of algorithmic management practices has been observed in a variety of sectors (see also the previous *section 3.1*), including logistics (comprising transport, storage and delivery services), retail, hospitality (e.g., accommodation), other service industries (e.g., banking, call centers), manufacturing, and public services (e.g., healthcare, police).

In contradistinction to the use of algorithmic management in DLPs, its implementation in conventional work environments is distinguished by its integration within **existing structures and processes of work organisation**. This complicates the identification of algorithmic management **in traditional work contexts**, and it creates the possibility for new forms of algorithmic management to emerge. Nevertheless, the prerequisites for such developments are as follows: firstly, **data** concerning employees and the work process to feed algorithms; secondly, the **processing and elaboration** of this data by algorithms; and thirdly, the **coordination and control** of employees by management decisions, which is made possible by the aforementioned first and second factors. The report published by the JRC-ILO provides an overview of how the implementation of algorithmic management systems gives rise to modifications in organisational structure, as illustrated in the figure below.

Figure 20. Algorithmic management and its implications in regular work settings

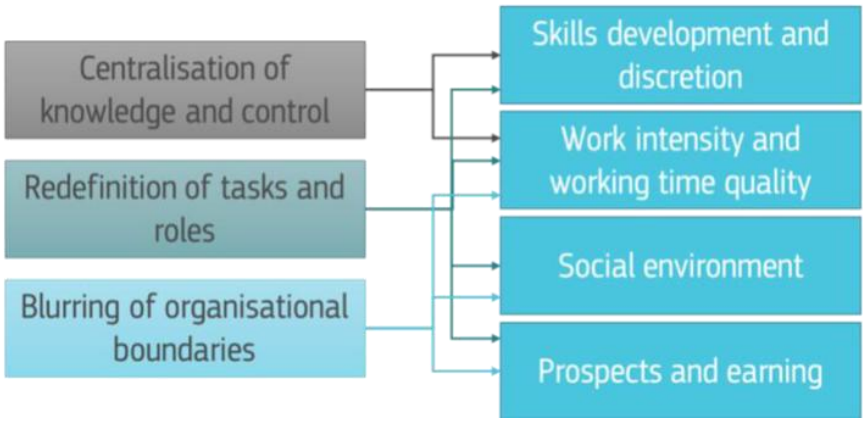
Source: Baiocco, Fernández-Macías, Rani & Pesole (2022, p. 18)

Implications for occupational safety and health

As shown in *Figure 20*, interactions between ALMA AI practices and pre-existing forms of work organisation lead to changes in work organisation. These include, for example, the centralisation of knowledge and control in the course of collecting and processing large amounts of data about workers and their work. In conjunction with these centralisation trends, jobs and tasks are becoming increasingly standardised, middle management is shrinking, and work is being atomised across occupational groups. In addition, ALMA has the potential to blur organisational boundaries by shifting typical vertical relationships within companies to horizontal relationships typical of market transactions.

These organisational changes have an impact on the quality of jobs. The JRC/ILO report links the centralisation of knowledge and control, in particular, to a loss of autonomy and deskilling, as well as to an intensification of work and a deterioration in the quality of working time. All of these effects could be considered as psychosocial risk factors in the OSH field, considering also the ALMA-AI project approach (see *Figure 5* and *section 2.2*). These aspects are also negatively influenced by the redefinition of tasks and roles, which has an additional negative impact on the social environment, career prospects, and income (indicators of social support and rewards). The blurring of organisational boundaries has a particularly negative impact on the intensification of work and the quality of working time, the social environment, prospects and income (*Figure 21*).

Figure 21. Links between changes in work organisation and job quality dimensions



Source: Baiocco, Fernández-Macías, Rani & Pesole (2022, p. 21)

In summary, the organisational changes in work brought about by ALMA hurt job quality in several ways and represent psychosocial risk factors. These can lead to disorders and illnesses such as anxiety or depression, but also cardiovascular disease or musculoskeletal problems, as highlighted by the JRC-ILO report based on literature sources (see also *section 2.2*).

Preventive measures

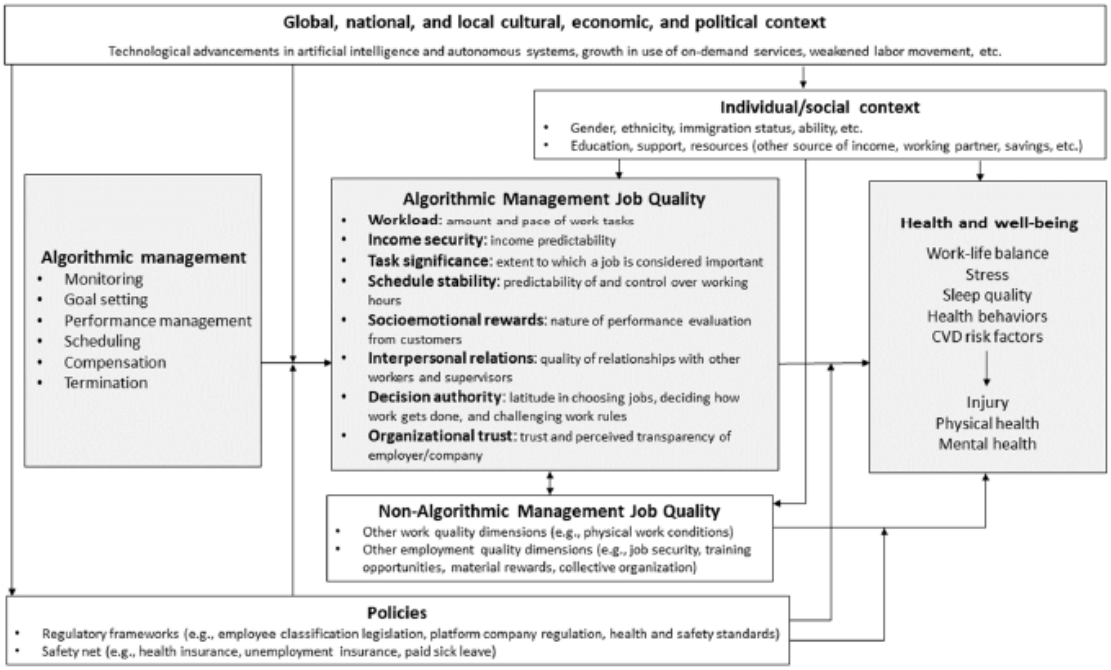
At the end of the JRC-ILO report, the authors outline policy options to counteract the potentially negative effects of algorithmic management and to create a better balance between employers and employees in the digital age. Based on the situation in 2022, recommendations are formulated for expanding the legal framework to balance the centralisation of power and control. Employees should be given sufficient rights regarding the use of their data and access to the criteria and functioning of algorithms. In addition, the paper recommends the creation of participatory mechanisms and bodies to negotiate and monitor algorithmic management. This is to prevent abuses against workers and their fundamental rights, and to ensure a fair distribution of benefits.

Literature reviews on platform work

The literature review of Emilia Vignola, Sherry Baron, Elisabeth Abreu, Mustafa Hussein and Nevin Cohen (2023) related to "Workers' Health under Algorithmic Management" highlights how ALMA can significantly reshape job quality for platform-based delivery workers. Their investigation is based on their assumption that ALMA – which its functions are the same used in our analysis and that were developed by Parent-Rocheleau and Parker, and their colleagues – influences numerous dimensions of job quality linked to worker health, including workload, income security, task significance, schedule stability, socioemotional rewards, interpersonal relations, decision authority, and organisational trust (*Figure 22*), being the majority of these ALMA effects understood previously as psychosocial job demands, but also as a job resource and a sociotechnical factor in the cases of the two latest factors (also included all in the ALMA-AI approach explained in the *section 2.2* and summarised in *Figure 5*).

Vignola et al. (2023) apply a narrative literature review approach, synthesizing the interdisciplinary findings rather than presenting new empirical data, yet their findings remain highly relevant to the scope of this report.

Figure 22. Health-related job quality dimensions influenced by algorithmic management



Source: Vignola, Baron, Abreu, Hussein & Cohen (2023, p. 2)

The paper claims that when ALMA is used to dictate various core work management functions such as managing tasks, schedules, payments, and performance, this often leads to **intensified workloads, time pressures, and unsafe behaviours** in platform workers (Vignola et al. 2023). Additionally, it outlines how workers report **unstable incomes and a lack of schedule stability**, as the algorithm-based pricing, tipping, and ranking systems undermine financial security, making it difficult to plan or rest effectively. The paper also recognises a **loss of meaning** in these jobs, which is due to data-driven performance metrics prioritizing efficiency over the human context (Vignola et al. 2023). **Psychosocial effects** are also highlighted in this literature review. Due to the constant surveillance, along with the threat of deactivation of the work, and dependence on customer ratings, this can lead to **anxiety, emotional exhaustion, stress, and lack of trust** in the platforms. Additionally, their decision-making **autonomy** is reduced by the non-transparent systems and limited access to information (Vignola et al. 2023).

Essentially, the report from Vignola et al. (2023) highlights how ALMA reshapes job demands that lead to significant risks to platform workers' OSH. This reinforces the need for interventions to address both the intensity and structure of these demands in platform-based work and in more traditional workplaces, since ALMA is also being introduced there.

Similarly, Bruno Felix, Diego Dourado and Valcemiro Nossa (2023) focus on platform workers, with a particular concentration on the relationship between well-being and platform work under ALMA, integrating the perspectives on both the need for security and desire for autonomy. The authors argue that these elements are not mutually exclusive and that these **well-being** outcomes can depend on the fit between individual worker preferences and the values promoted by the platforms (Felix et al., 2023).

On the one hand, the literature review highlights that platform work tends to **lack the physical and psychological security** that is traditionally provided by employers, e.g., stable income, benefits, and protection from overworking. This insecurity can lead to numerous OSH risks for these workers, including **emotional stress, anxiety, and reduced job satisfaction**. Since ALMA automates decisions based upon work allocation and performance evaluation, the authors recognise widespread criticism for reinforcing these conditions by developing **asymmetric information, power relationships, and reducing transparency** (Felix et al., 2023).

On the other hand, other studies assessed in this literature review highlight that platform work has the **potential to enhance well-being through increased autonomy**. The workers may value the flexibility that platform applications can offer, such as choosing schedules or controlling workload. This kind of autonomy can be empowering, especially for those who prioritise their independence over stability (Felix et al., 2023).

As a means of appeasing both of these views, the authors refer to the Person-Organisation Fit theory, suggesting that **worker well-being is highest when there is alignment** between workers' preferences (for autonomy or security) and the platform's operational model. When there is **misalignment** (for example, a worker seeking stability in an autonomous environment), **stress and dissatisfaction are more prevalent**. The authors also introduce the Paradox Theory, which argues that autonomy and security are not a twofold choice. This theory would imply that workers and organisations that adopt the 'paradox mindset' – where security and autonomy are recognised as being interdependent – can achieve a more sustainable well-being.

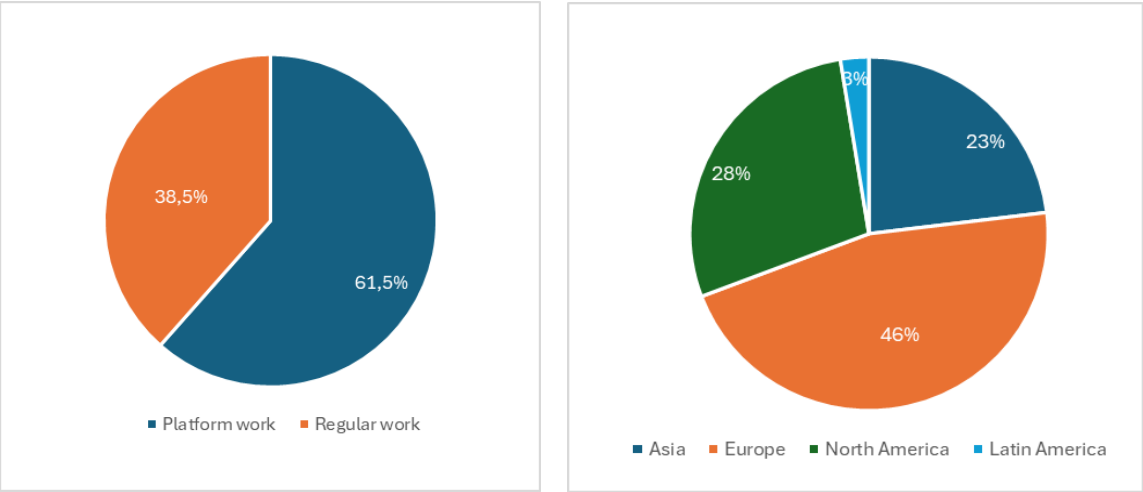
In summary, the literature review of Felix et al. (2023) suggests that the impacts of platform work on well-being are not fundamentally positive or negative. Rather, the impacts depend on the interplay between individual preferences, the organisational procedures, and the ability to balance security and autonomy in a way that supports long-term health and satisfaction.

IV. NEW EVIDENCE ON ALGORITHMIC MANAGEMENT EFFECTS (2022-2024)

As the main result of the scientific literature review process (see *section 1.2* on Methodology), a total of **33 papers** were selected because they contain evidence from 2022 to 2024 on the association between ALMA and psychosocial risks or OSH implications. Additionally, **6 more reports** were included in the final analysis, as they show **empirical evidence** either gathered by quantitative studies (e.g., statistical analyses) or created by qualitative ones (e.g., ethnographic studies or interviews). All these publications were examined, dividing them into types of research methods, but also separating the findings of new evidence between the platform work domain and the general regular work. This new evidence from 2022 to 2024 is **described in this chapter**.

To this extent, it is important to note that the 39 publications on new evidence from 2022 to 2024 revealed some current trends in the research field of ALMA related to OSH (*Figure 23*). First, the studies regarding psychosocial factors in this new form of organisation are increasingly **delving into regular work** (38.5% of the selected publications), although the **platform work domain keeps its protagonism**, as the proportion of selected evidence-based publications corroborates (61.5% of selected studies are in platform work). Another trend is the growing research interest in this field in **regions across the world**. Although initially ALMA research was focused on North America reality (Urzi & Curtarelli, 2021), in our literature review, new evidence is prominent **in Europe** (46% of studies), and then followed by **Asia** (28%), mainly in China.

Figure 23. Percentage of selected publications by type of work and research region



Source: Own elaboration

4.1. Statistical analyses and data-based evidence on ALMA

In this section, all the papers were gathered by the scientific literature review, but some reports on the grey literature review are also described, in which new evidence is created based on quantitative studies (data analysis, surveys, questionnaires), divided into those focusing on platform work (*subsection 4.1.1*) and those related to traditional regular work (*subsection 4.1.2*).

4.1.1. Data-based evidence on ALMA in platform work

Giuliana Buresti (INAIL, Italy), Heidi Lahti (FIOH, Finland) & Benjamin Paty (INRS, France)

This subsection centres on nine studies conducted in the platform work, encompassing gig arrangements such as food delivery, ride-hailing, and crowdwork. As we have already written, while ALMA can streamline workflows, enhance efficiency, and sometimes foster positive job resources (e.g., fair compensation, better coordination, autonomy), it also can impose new demands. As documented across China, Europe and North America, these demands may manifest as psychosocial risks (e.g., stress or burnout) if not effectively mitigated by human oversight and intervention, fairness mechanisms, or other protective factors.

1) Job Demands and Psychosocial Pressures

A recurring theme in the literature is that the use of algorithmic systems may intensify job demands, particularly regarding workload and performance pressures. In addition, many studies have examined how socio-technical characteristics of ALMA systems, such as algorithmic transparency and fairness, mediate or moderate these effects of ALMA on work and workers.

- **Time Pressure and Performance Demands**

Several authors explain how ALMA can heighten the speed and frequency of tasks. For instance, Maffie (2024) describes how “Instacart Shoppers” are incentivised to move quickly, often leading to tensions with in-store employees and creating an environment fraught with stress. Similarly, Semujanga and Parent-Rocheleau (2024), based on survey data from 962 gig workers (83.5% US; 13.4% India) with AMQ-based items (see Measurement section below), investigated how algorithmic compensation relates to time-based stress (measured as perceived time pressure and urgency) and procedural justice perceptions, and whether perceived algorithmic transparency moderates these relationships. Using hierarchical multiple regression analysis, the authors found that perceived exposure to algorithmic compensation is associated with increased time-based stress, and that this relation was not influenced by transparency.

- **Workload and Cognitive Stress Appraisals**

In a study on food-delivery riders in China (98% male; ages 18–59) using the Job Demands–Resources (JD-R) framework, Lu et al. (2024) examined how the level of algorithmic involvement in decision-making processes (particularly handling customer complaints) influenced riders' commitment to service-quality, and through that commitment, their likelihood of referring others to the platform. They also investigated whether the relationship between the level of algorithmic involvement and riders' commitment to service quality was moderated by challenge demands, operationalised as workload. Using a 1×4 between-subjects experimental design, the authors manipulated the level of algorithmic involvement across four conditions (scenarios ranging from low to high) with 1,362 food-delivery riders. They also conducted 21 semi-structured interviews aimed at enriching the qualitative interpretation. Analysing the data through regression and thematic analysis, they found that workload moderated the relationship between algorithmic involvement and commitment to service quality: under high workload, the negative effect of algorithmic involvement was significantly weaker. They also found that high levels of algorithmic involvement, especially when AI decisions dominate over human input, could exacerbate stress. More precisely, concerning the **stress appraisal** mechanism, they showed that when algorithms dominate and human review is minimal, couriers tend to perceive management as a *hindrance demand*, which triggers frustration and stress. In contrast, when some level of **human support** is available, the same algorithmic processes are more often appraised as a *challenge demand* that can motivate improved performance. In sum, the same algorithmic system can either generate stress or foster engagement, depending on the presence of human input (a resource), workload (a challenge demand), and the coping strategy chosen — defensive ("work more to compensate") versus proactive ("serve better to prevent complaints").

Relatedly, Li, Lu, Hu and Gupta (2024) examined how two key features of ALMA — algorithmic monitoring and perceived algorithmic fairness — influence work engagement among 364 online car-hailing drivers in China (73.6% male; 51% part-time). Like the previous study, grounded in the Transactional Theory of Stress, the authors argue that these ALMA features shape engagement indirectly through drivers' cognitive stress appraisals. Specifically, the study investigated how ALMA may evoke two types of cognitive appraisals: challenge appraisals, where algorithms are perceived as opportunities for growth, and hindrance appraisals, where they are seen as obstacles that thwart goal achievement.

Using a self-report questionnaire adapted from established scales and analyzed via Partial Least Squares Structural Equation Modeling (PLS-SEM), Li et al. (2024) found that **stress appraisals** fully mediated the link between algorithmic monitoring **and work engagement** and partially mediated the link between algorithmic fairness and work engagement. Strong algorithmic monitoring was associated with increased hindrance appraisals, which in turn reduced work engagement. In contrast, perceived algorithmic fairness increased challenge appraisals and reduced hindrance appraisals, thereby fostering higher engagement. However, it is important to note that, rather than examining psychosocial risk factors related to job demands and resources, the study focused on individual-level cognitive appraisals, leaving the potential psychosocial risk factors influencing these appraisals unaddressed.

- **Insecurity, Injustice, and Unsupportive Interaction**

Hajiheydari and Delgosha (2024) conducted a study among 307 gig workers across the US, UK, and Canada, recruited through online worker communities (Uber, TaskRabbit, Deliveroo). Using an online survey based on adapted validated scales and analysed within the Job Demands–Resources (JD-R) framework using Structural Equation Modeling (SEM), the authors examined how platform features function as job demands or resources. Specifically, they identified algorithmic compensation, work autonomy and information sharing as job resources, and job insecurity, unsupportive algorithmic interaction and algorithmic injustice as job demands. The results showed that job resources significantly boosted worker engagement, with algorithmic compensation having the strongest effect. In contrast, job demands of job insecurity, unsupportive algorithmic interaction and perceived algorithmic injustice were associated with **increased burnout**, as they contributed to feelings of isolation and dehumanisation. The study also revealed that job resources moderated (buffered) some of the negative effects of demands on burnout, though not uniformly across all demand-resource combinations.

- **Monitoring and Algorithmic Quantification (“Being Reduced to a Number”)**

In Wang et al. (2022), the authors distinguish between observational monitoring (where workers do not actively participate in the data-collection process) and interactional monitoring (where platforms engage more directly with workers for feedback). Their study was conducted on 269 Chinese gig workers (matched from 315 to 269 responses), using a custom two-wave survey measuring observational *vs* interactional monitoring, and analysed through PLS-SEM with mediation and moderation tests. They found that observational monitoring negatively

influenced workers' cognitive engagement by reducing affective trust, whereas interactional monitoring had a beneficial effect.

Van Zoonen and colleagues (2023; 2024) conducted two quantitative studies to examine how different ALMA features influence the perceived meaningfulness of work. The first study included 412 participants across four major micro-task platforms (Clickworker, MTurk, Microworkers, and Prolific), while the second study focused on 1,291 Clickworker users. While the studies do not focus explicitly on OSH, the findings point to relevant psychosocial outcomes such as decreased perceived meaningfulness, identity challenges, and social disconnection.

In the 2023 study, data were collected via online surveys, and measurement items included ALMA-related features, work design characteristics (autonomy, skill variety, task identity, task significance, feedback), and meaningfulness of work. SEM was used to test how two facets of ALMA (algorithmic coordination and algorithmic quantification) influence work design characteristics and perceived meaningfulness. Algorithmic coordination refers to the automatic assignment of tasks and payment by the platform (e.g., when "the platform algorithmically determines which tasks you receive"), while algorithmic quantification captures the sense of being reduced to metrics or numbers (e.g., "evaluation reduces me to a number" or "it does not capture qualitative attributes"). The results highlight that algorithmic quantification was negatively associated with perceived autonomy, feedback, task significance, and task identity, and thereby reduced the meaningfulness of work. In contrast, algorithmic coordination was associated with increased autonomy, task significance, and feedback, and positively linked to perceived meaningfulness.

In the follow-up study, van Zoonen et al. (2024) further explored how ALMA affects workers' identity and social experiences. They found that directive algorithmic control reduced meaningfulness and increased identity struggles and relational challenges, whereas algorithmic matching, which supports efficient task assignment, was positively associated with meaningfulness but not with identity. Notably, workers who experienced identity struggles or actively sought social recognition through peer interactions still reported relatively high levels of work meaningfulness, highlighting the complex role of ALMA in shaping workers' experiences.

2) Job Resources and Socio-technical Moderators as Mitigating Factors

In addition to ALMA often being associated with increased demands and stress, studies also indicate that it can undermine key job resources such as autonomy and task complexity. However, some research highlights conditions under which negative impacts of ALMA may be mitigated—particularly when elements like human oversight, fairness or transparency are woven into its design.

- **Autonomy and Job Complexity**

Parent-Rocheleau et al. (2024) demonstrated that higher exposure to ALMA (capturing five core functions using the AMQ) was associated with lower job autonomy and job complexity. These reductions in autonomy and complexity, in turn, predicted lower work engagement, suggesting that ALMA can indirectly erode motivational outcomes via diminished job resources.

- **Human Oversight and Social Support**

Lu et al. (2024) emphasise that human involvement in decision processes, such as the opportunity to appeal customer complaints to an actual person, can help alleviate stress induced by automated systems among couriers. Maffie (2024) similarly observes that co-worker support (e.g., from grocery-store employees) can offset algorithmic pressures on gig workers.

- **Transparency and Fairness**

In Semujanga and Parent-Rocheleau (2024), algorithmic transparency strengthens procedural justice perceptions, buffering the negative effects of automated pay systems. Li et al. (2024) also show that algorithmic fairness reduces the likelihood of hindrance appraisals, positively influencing work engagement among ride-hailing drivers.

3) Key Outcomes for Occupational Safety and Health (OSH)

Several studies highlight critical psychosocial and mental health outcomes associated with ALMA systems, including stress, burnout, reduced engagement, and workplace tensions—all of which can undermine worker well-being and safety over time. At the same time, certain ALMA design choices, such as interactive or feedback-based monitoring, may help foster trust and engagement, offering a potential buffer against negative OSH impacts.

- **Stress, Burnout and Reduced Meaningfulness**

Several studies (Lu et al., 2024; Hajiheydari & Delgosha, 2024; van Zoonen et al., 2023; 2024) suggest that algorithmic controls can yield elevated stress levels, especially when decisions feel opaque, metrics-driven, or disproportionate. Over time, sustained stress can increase the risk of burnout, emotional exhaustion and mental health challenges.

- **Engagement vs. Disengagement**

Drivers' and crowdworkers' perceived fairness (Li et al., 2024) or a sense of meaningfulness (van Zoonen et al., 2023) can bolster engagement, which in turn improves overall well-being. However, if algorithms are perceived as unfair or dehumanizing, engagement declines, potentially leading to turnover or stress-related ill-health. Likewise, as previously mentioned, engagement can be influenced by the effects of ALMA on job autonomy and complexity (Parent-Rocheleau et al., 2024).

- **Potential Spillover Effects**

In the grocery delivery, Maffie (2024) underscores how pressures placed on gig workers can spill over to conventional employees, exacerbating workplace tensions. This finding raises the possibility that algorithmic pressures not only affect immediate platform workers but can also alter the broader work environment, with implications for collective well-being and safety.

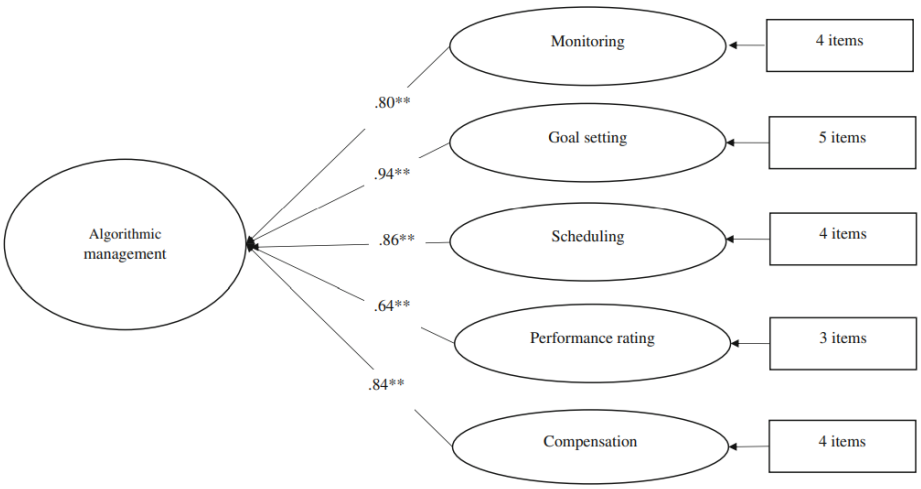
- **Algorithmic Monitoring and Psychosocial Outcomes**

Wang et al. (2022) point out that interactional monitoring—involving some level of communication, feedback or dialogue with workers—can boost cognitive work engagement through affective trust and affective commitment. This finding contrasts with observational monitoring, which tends to decrease affective trust and reduce cognitive work engagement.

4) Measurement Instruments: The Algorithmic Management Questionnaire (AMQ).

Finally, one study highlights a newly developed and validated scale for assessing workers' exposure to ALMA that could be useful beyond the platform work context, for example, in traditional workplaces that use this new form of organisation. Parent-Rocheleau et al. (2024) developed a multidimensional 20-item questionnaire, the Algorithmic Management Questionnaire (AMQ), which they validated to assess platform workers' perceived exposure to ALMA across five core management functions: algorithmic monitoring, goal setting, scheduling, performance rating, and compensation[13]. Across three survey samples collected in Canada and Australia among gig-workers (total N = 1,332), the authors demonstrated the content and factorial validity of the scale (see the Confirmatory Factor Analysis measurements visualised in *Figure 24*). Also, they associated the AMQ with the effects on autonomy and complexity of tasks, as previously was pointed out in this subsection, showing predictive validity of the AMQ for both (corroborating that a higher presence of ALMA is linked with a reduction in job autonomy and, additionally, a decrease in job complexity in platform work). Moreover, the AMQ predictive validation analysis demonstrates an indirect effect of ALMA, which could reduce the workers´ engagement by decreasing their job autonomy and the complexity of the tasks they carry out, as was also pointed out above.

Figure 24. Final measurements model of the Algorithmic Management Questionnaire (AMQ)



Source: Parent-Rocheleau et al. (2024, p. 31)

[13] The questionnaire is based on the previous framework created by Parent-Rocheleau and Parker (2022), which is used in the ALMA-AI approach (see *section 2.2*), although the dimension of `job termination´ was eliminated based on the statistical validation results (Parent-Rocheleau et al., 2024) of the previous six dimensions (Parent-Rocheleau & Parker, 2022).

4.1.2. Statistical evidence on ALMA in regular work around Europe

Jorge Martín (INSST, Spain) & Mairi Bowdler (TNO, The Netherlands)

Although most of the new evidence-based research from 2022 to 2024 focuses on platform work, particularly quantitative studies have a significant number of scientific articles nowadays that also regard regular workplaces (see *Figure 23* at the introduction of this chapter). Seven of the articles analysed in this report investigated the effects of ALMA on regular work, and two of the grey literature reports presented statistical analysis of surveys related to ALMA, psychosocial factors and OSH implications in different countries, including at a European level.

It is important to note that cutting-edge surveys were conducted by the ALMA-AI project observers' institutions. Beyond the particular and more recent *Algorithmic Management and Platform Work* (AMPWork) survey, carried out by the JRC of the European Commission in 2022 (only in Spain and Germany, although it has a representative sample collected in-person), the EU-OSHA included questions related to ALMA in their last published surveys (ESENER 2019 and OSH Pulse 2022). EU-OSHA initially included these questions about technologies to manage workers in the *European Survey of Enterprises on New and Emerging Risks* (ESENER-3) in 2019[14].

The resulting dataset was used to corroborate with a pioneering statistical analysis at a European level – previously, the evidence come mainly from qualitative studies, specific sectors or countries, especially from USA – demonstrating the association between digital tools for worker management and a higher presence of psychosocial risks or factors (Urzi & Curtarelli, 2021). The statistical analysis of ESENER-3, conducted by Cesira Urzi (JRC) and Maurizio Curtarelli (EU-OSHA), was the first of a representative sample that went beyond just platform work. It demonstrated that the use of machines or software for monitoring performance and to determine the content or the pace of work, in European enterprises, increased the likelihood of workers experiencing psychosocial risks. These risks were measured through an index that included both high job demands (such as time pressure, long working hours, and dealing with customers, patients or pupils), and lack of job resources. Indicators of low levels of job resources included poor communication or cooperation within the organisation (reflecting a lack of social support), as well as a fear of job loss (as an indicator of low job security).

[14] In this third wave of ESENER, a total of 45,420 establishments with at least 5 employees from 33 participating European countries were surveyed.

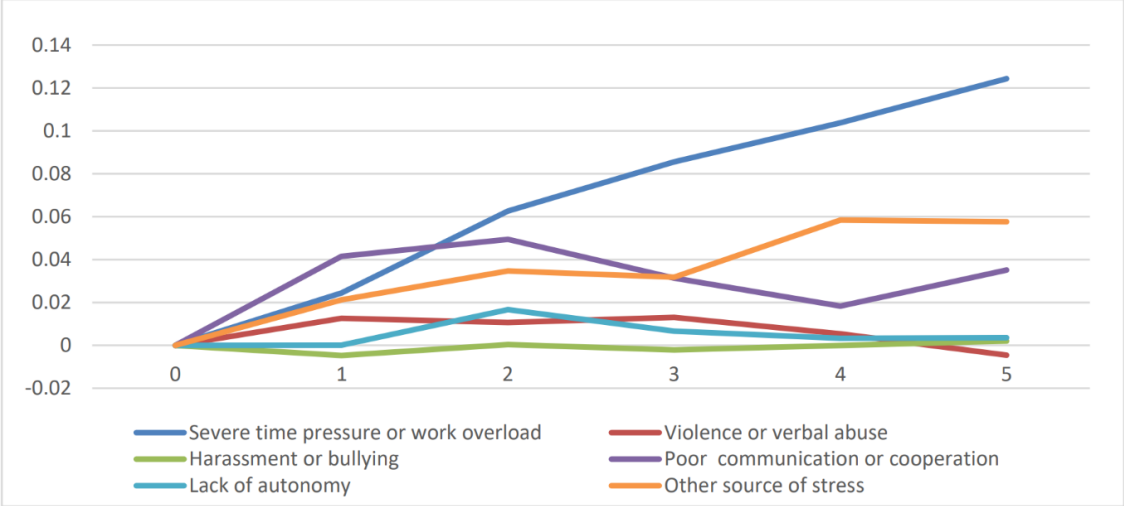
For this report, the analysed new evidence included a total of 7 scientific articles (Bujold et al, 2022; Kinowska & Sienkiewicz, 2023; Zhang et al., 2023; Segovia-Perez et al., 2023; Jago et al., 2024; Li et al., 2024; Granulo et al., 2024) and 2 grey literature reports (Pesole, 2023; Jensen et al., 2024). None of these reports includes the aforementioned pioneering statistical analysis carried out by these researchers of the EU-OSHA and the JRC. Rather, one of the scientific papers in the literature review period covered (2022-2024) uses another representative survey on a European scale to execute a statistical analysis about the implications of ALMA on OSH (Kinowska & Sienkiewicz, 2023). An additional two of the grey literature reports, included in the analysis, generated quantitative evidence using the OSH Pulse 2022 survey carried out by the EU-OSHA (Pesole, 2023) and a new survey in different Nordic countries funded by the European Parliament (Jensen et al., 2024). Further, another selected scientific article used an experimental design (Zhang et al., 2023), and the rest of the five scientific articles show evidence through statistical analysis of their own data collection, but most of them are focused on specific sectors, industries, countries or particular factors involved (Bujold et al, 2022; Segovia-Perez et al., 2023; Jago et al., 2024; Li et al., 2024; Granulo et al., 2024).

The main findings are presented equivalently to those in *subsection 4.1.1*, dividing between job demands and psychosocial pressures, job resources and potential benefits, and key outcomes for OSH, including an additional part to highlight the evidence about relevant moderators of the association between ALMA and psychosocial factors or OSH implications.

1) Job Demands and Psychosocial Pressures

The EU-OSHA report developed by Annarosa Pesole (2023) highlights the surveillance and monitoring practices of ALMA and AI tools on remote workers. However, the report also shows important evidence of the impact of ALMA in all regular work, using the OSH Pulse 2022 survey data, which reveals a higher presence of psychosocial risks and factors when there is a greater adoption of ICT devices or digital technologies in the job, but also when ALMA practices are more intense. The OSH Pulse survey collects data involving 27,250 workers from EU-27 Member States, plus Iceland and Norway, and initially describe the consequences of ICT or digital technology adoption, showing data about the use by workers of: desktop; portable devices (laptops, tablets, smartphones or others); wearables; broadband technology; AI machine; and interacting robots. As the first important indicator, it is highlighted that 78% of workers in Europe use at least one of these digital technologies.

Figure 25. Psychosocial risks, factors and degree of digital technology adoption



Source: Pesole (2023, p. 14)

As *Figure 25* visualises, the digital technology adoption (using a cumulative index summing up the use of the six different technologies previously listed) is related to psychosocial risks. When more ICTs are involved, job demands increase, with severe time pressure and excessive workload becoming more common as digital technology use is intensified. On the other hand, job resources do not appear to be seriously impacted by more technological adoption, although a slight incline in autonomy, and especially poor communication, is observed when workers use one or two ICTs. Related to OSH outcomes, other sources of stress increase progressively as more ICTs are involved, but it also seems that more technological adoption does not increase violence or verbal abuses, harassment or bullying. On the contrary, the analysis shows a slight reduction of these two psychosocial risks when more ICTs are used in regular work in Europe.

Second, and most importantly for the ALMA-AI project, the EU-OSHA study (Pesole, 2023) executes a multivariate analysis by Ordinary Least Squares (OLS), obtaining evidence about the ALMA impact on psychosocial risks, but also on OSH outcomes. This empirical analysis compares the association between psychosocial risks and factors with surveillance, monitoring or algorithmic management practices. On the one hand, these practices are combined in an "organisational model" index that includes several items in the analysis that are clearly part of the "algorithmic management" conceptualisation and functions adopted by the ALMA-AI

project[15]. On the other hand, the "psychosocial risk" index combined the above showed items about the presence of psychosocial risks or factors (visualised in *Figure 25*), being severe time pressure or work overload (clearly a high job demand); violence or harassment (psychosocial risk *per se* or OSH outcome); poor communication or cooperation (that implies inadequate levels of the social support job resource); lack of autonomy (also a negative indicator of job resources); and other stress causes (psychosocial risk or OSH outcome). The most important result of the empirical analysis is that the use of ALMA in European workplaces increases the prevalence of psychosocial risks or factors by 0.210 (Pesole, 2023). Namely, when the ALMA index increases by one time, the psychosocial risk index increases by 21%.

Adding other variables to the mentioned OLS analysis (Pesole, 2023), the report also shows that the impact of ALMA in psychosocial risks can be more serious for clerical workers and skilled workers compared to professionals and administrators, with the former more likely to face an automation of their cognitive tasks and the corresponding monitoring procedures, both of which track speed and specific steps of their work. An important additional finding is that remote work[16] reduced the link between ALMA and psychosocial risks. Namely, it seems that, although being monitored, rated by third parties or determined by automatic allocation of tasks or schedules, having the flexibility to work where the worker chooses outside the enterprise reduces psychosocial risks. These remote workers, especially those who work at home, achieve better job resources, as they often enjoy a greater sense of autonomy, but also working from home can cut down commuting and generally improve overall work-life balance.

Although a reduction in psychosocial risks impact of ALMA is observed in remote workers, it is necessary to reinforce that, as a general result, the OSH Pulse survey multivariate analysis (Pesole, 2023) corroborates that ALMA negatively influences working conditions in Europe, increasing the probability of having excessive job demands (time pressure or work overload), inadequate job resources (lack of autonomy or poor communication) or directly suffer psychosocial risks (harassment, violence or stress).

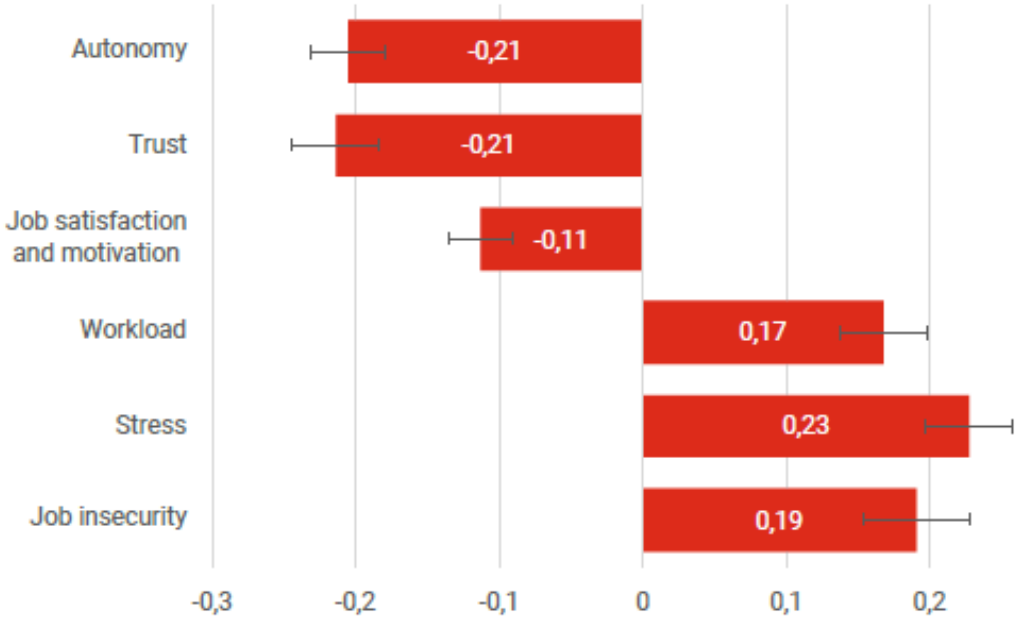
[15] The "organisational model" index in the EU-OSHA report (Pesole, 2023) contains responds to questions on the use of digital devices to determine the speed or pace of work, to increase surveillance, to supervise or monitor it (both an expression of "monitoring" function of the ALMA-AI model), to allocate automatically tasks or working time or shifts ("goal setting" and "scheduling" functions), performance rated by third parties ("performance ratings") and monitor heart rate, blood pressure or postures (not strictly include as function in the ALMA-AI approach). Therefore, the "organisational model" index can be considered mainly as an indicator of the intensity of "algorithmic management".

[16] Remote work is operationalised as all work that is performed outside the enterprise premises (e.g., work at home, in the client premises, in a vehicle, or in public spaces)

In a similar way to the results of the EU-OSHA report, the statistical analysis of the survey conducted by Magnus Thorn Jensen, Gerard Rinse Oosterwijk and Asbjørn Sonne Nørgaard (2024) in Nordic countries[17] highlighted that the use of ALMA is creating negative effects. These undesired impacts are seen in two main ways: reducing positive outcomes or job resources (autonomy, trust, satisfaction or job security) and increasing job demands, such as workload (see *Figure 26*). This situation is prone to negative consequences, as this statistical analysis shows increased stress when ALMA is used more in companies.

Moreover, it is important to reinforce that this quantitative study evaluates the effect of ALMA on a specific job demand, which has been well-corroborated as being associated with work-related stress for decades, since the first DCS model was proposed by Karasek (1979). Specifically, two questions are used to measure the perceived workload ("I generally have enough time to complete my tasks" and "there are often not enough people or staff to get all the work done").

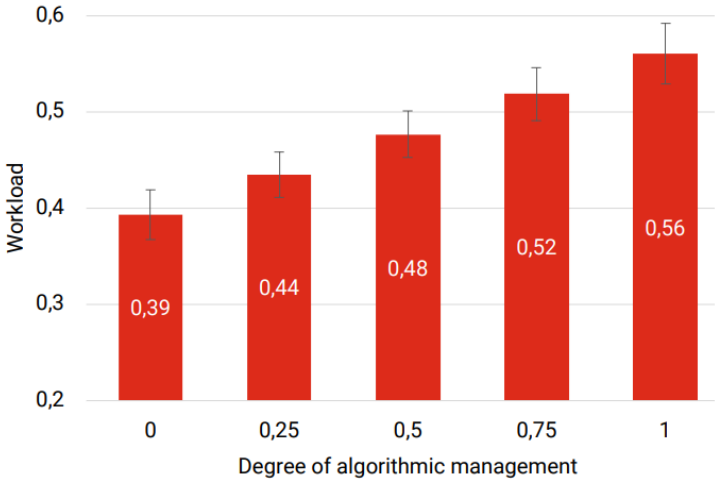
Figure 26. Estimated effects of ALMA on different job resources, workload and stress



Source: Jensen et al. (2024, p. 41)

[17] A total of 5,141 respondents completed the survey in Denmark, Sweden, Finland and Norway. This study is the result of an alliance of different political foundations, leading by FEPS, financed by the European Parliament.

Figure 27. Predicted level of workload by degree of ALMA



Source: Jensen et al. (2024, p. 39)

Combined, the previously described questions are statistically associated to different degrees of ALMA, which, on the other hand, is an index that mixes seven indicators (including different uses for monitoring, goal setting, scheduling and performance rating functions). As *Figure 27* shows, the workload increases when more ALMA functions are involved in the enterprises. This finding implies that one of the main concerns around the ALMA impact and the use of AI in the workplace is becoming a reality. These digital developments are creating an intensification of work and, therefore, at least in Nordic countries, are elevating the job demands for workers. Furthermore, it shows that the intensity of ALMA functions application plays a role in creating a higher level of workload and job demands. Namely, it seems from this evidence-based quantitative study in Nordic countries that when more ALMA functions are used in an enterprise, there is a higher likelihood of experiencing excessive workload or job demands.

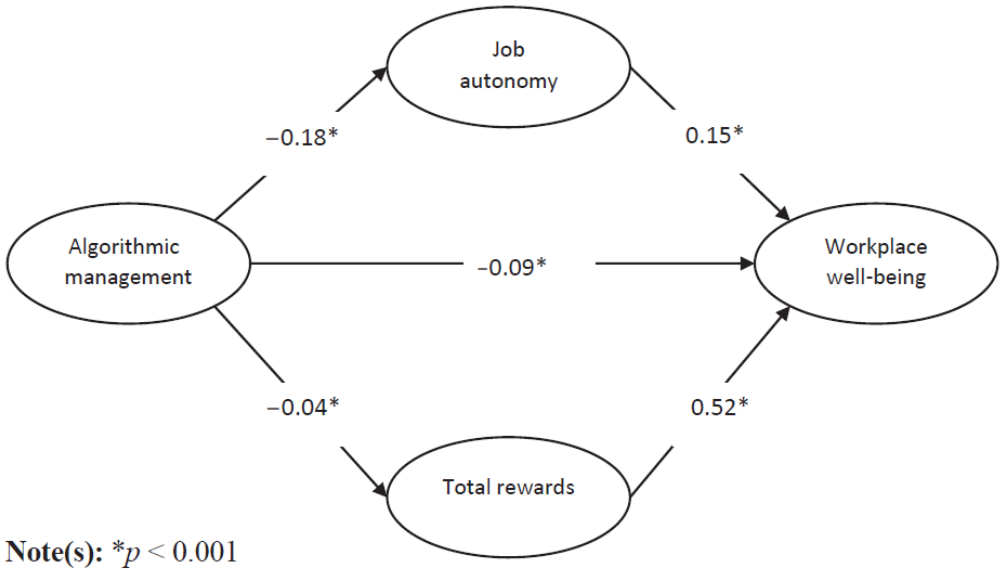
2) Job Resources and Potential Benefits

A significant number of the scientific articles analyzed for the report tended to focus on job resources or the potential benefits of ALMA. However, the quantitative studies focusing on regular work point out that instead of reinforcing the job resources to deal with work demands, ALMA reduces them, thereby diminishing the opportunity to boost positive outcomes. The clearest empirical study that shows this general finding was conducted by Hanna Kinowska and Łukasz Sienkiewicz (2023), based on data from the Eurofound and Cedefop survey of managers from 21,869 companies in 2019. Their statistical analysis using Structural Equation Modeling

(SEM) at a European level, despite a positive relationship between ALMA and well-being, verifies that the use of ALMA has a negative association, although moderate, with workplace well-being (an index constructed using variables that capture absenteeism, motivation, employee retention, and relationships between managers and workers).

Moreover, the analysis shows that ALMA has a greater impact when it influences autonomy and, to a lesser extent, rewards[18]. *Figure 28* visualises the model tested by SEM, showing with beta indicators that the direct weight of association between ALMA and workplace well-being is lower (-0.09) than when it is influenced through job autonomy (-0.18), being also the least weight when ALMA and well-being are associated by rewards as moderator (-0.04). In other words, the statistical analysis of European companies corroborates that ALMA especially reduces well-being in regular workplaces by reducing job autonomy. This indirect effect implies that ALMA is not necessarily a driver for reducing well-being, but, as it is nowadays applied in forms that reduce job resources, such as autonomy, is producing an undesired impact on some of the potential positive outcomes that, as a new form of organisation, could propel.

Figure 28. Association between ALMA, well-being, and psychosocial factors as mediators



Source: Kinowska & Sienkiewicz (2023, p. 33)

[18] Rewards are, in line with the ERI model, not only operationalised as economic incentives, but also with aspects such as the work being a stimulating activity or generating opportunities for professional development. For this reason, it includes the concept of rewards of Siegrist, but also the intellectual or skill discretion of the DCS model about the specific job resource of control over work (see *section 2.2*).

This previous argument is more logical to the extent that the study also showed that the variance in well-being was largely explained by rewards (almost 50%) and, more tenuously, by autonomy or control over work (18.2%), while, for its part, algorithmic management explained very little of this general level of workplace well-being (only 2.8%). In short, although this study showed that algorithmic management could influence well-being in regular work, by being used as a control mechanism (reducing the autonomy perceived by workers), other factors were directly more explanatory, such as rewards.

The results of all the described statistical analyses (Pesole, 2023; Kinowska & Sienkiewicz, 2023; Jensen et al., 2024) verify that, as is implemented today, in general, ALMA increases job demands but also reduces or limits job resources and opportunities for OSH.

First, regarding the relevance of how ALMA is implemented nowadays, an experimental study corroborates not only the importance of different components of job autonomy (what, how, and when) but also that being managed by humans or AI and algorithms may not be the key aspect. As the authors concluded, regarding potential positive OSH outcomes, «people's motivation to pursue goals does not become weaker when an AI algorithm instead of a human takes the role of management», pointing out that «the importance of not treating AI [*or algorithmic management*] as a general category but examining what AI systems actually do (e.g., restricting *what*, *when* or *how*)» (Zhang, Sankaran & Aarts, 2023, p. 581).

Second, considering the potential restriction of job autonomy and the previously described statistical analyses results, the same finding can be concluded by the rest of the scientific papers that delve into various sectors and other job resources or moderating factors. For example, with a sample of workers in across sectors in the USA, it was demonstrated that ALMA generates a reduction of perceived trust and status (Jago et al., 2024), while in China the use of ALMA is associated with a loss of creativity to the extent that limits knowledge combination capability and goal achievement in the Information Technology service sector (Li et al., 2024). In the case of a study conducted in around 500 workers in the transportation, distribution and logistics sector, it is corroborated that the use of ALMA in allocating tasks – "goal setting" function – reduces the prosocial motivation of the workers, because it is applied in a way that the coworkers are seen as instruments (Granulo et al., 2024). This prosocial motivation – conceptualised as a desire to promote the well-being of others in the workplace – can be understood as a job resource or even as a reward if it is used to increase esteem or social recognition in the

workplace. Finally, another gathered evidence regarding job resources is the research conducted by Segovia-Perez et al. (2023), which assesses the effects of ALMA on hospitality workers specifically, since the implementation of AI and ALMA systems in this industry appears to be tied to a high employee turnover and discrimination. In order to investigate these interactions, the researchers administered a survey targeting hospitality workers across the USA. The survey accumulated 450 valid responses, which spanned various hospitality activities, such as the food and beverage sector and lodging/accommodation. The results were in line with other previous research regarding job resources, gathered by the authors (Segovia-Perez et al., 2023), that implementing ALMA systems can result in feelings of alienation and loneliness (clearly a lack of social support), diminished worker autonomy and imbalances in power dynamics. Furthermore, as workers become more aware of the systems' negative impacts on their jobs, they tend to view their work environment and job security more negatively. The results from the survey also revealed a connection with workers' belief in potential job replacement by AI, feelings of work isolation and workplace discrimination. Additionally, a potential link was also found between ALMA and discrimination within an organisation (Segovia-Perez et al., 2023).

In summary, as in the rest of the quantitative studies mentioned, these new evidence-based scientific articles from 2022 to 2024 on ALMA show that, nowadays, it reduces the job resources of workers and, therefore, limits the opportunities and benefits for OSH that could be created to the extent that this use of algorithms or AI represents a new form of work organisation.

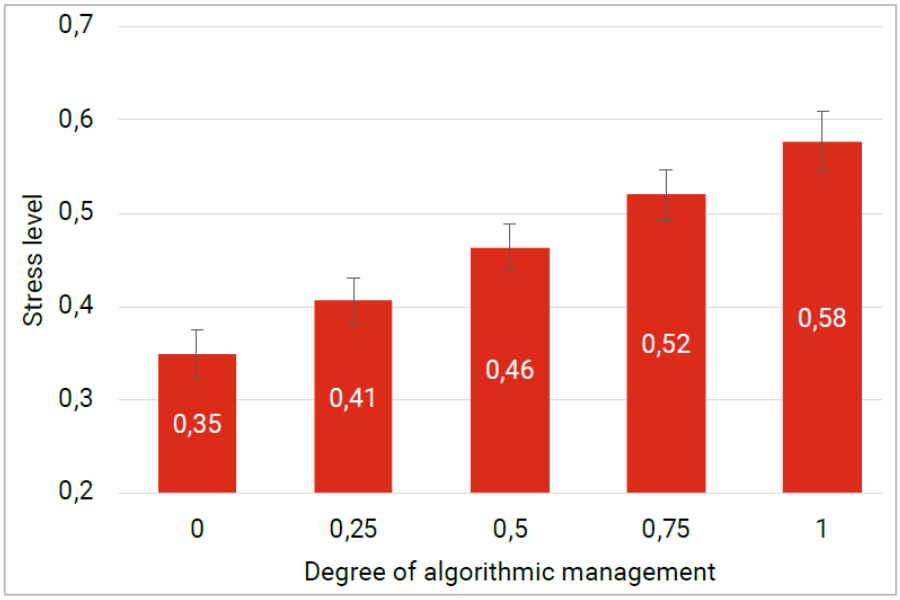
3) Key Outcomes for Occupational Safety and Health (OSH)

As previously highlighted, the literature review shows evidence mainly around the effects of ALMA in psychosocial factors, delving into job demands or resources that can lead to different OSH implications. Nevertheless, the gathered evidence in quantitative studies in regular work shows that ALMA nowadays impacts on psychosocial factors at levels that are prone to create OSH risks (such as stress or burnout), instead of benefits. The results described in the seven articles and two reports, which generate quantitative evidence, show that ALMA leads to higher job demands and fewer job resources.

However, regarding the direct evidence on OSH implications, some of them show a higher level of stress when ALMA is applied. For example, when different uses or functions of ALMA are involved, stress increases. Specifically, in the study on Nordic countries (Jensen et al., 2024), the cumulative use of the ALMA functions – goal setting (allocation of tasks), scheduling (of shifts),

performance rating (evaluation and leaderboard) and monitoring (location tracking, monitoring work speed and monitoring working time/breaks) – allowing the generation of an ALMA index that show the intensity of the use of algorithms or AI to worker management. As *Figure 29* visualises, when the degree of ALMA grows, a progressive increase in work-related stress occurs (psychosocial risk measured by asking workers if they have experienced signs of stress in the past 3 months, e.g. sleep problems, difficulty concentrating, heart palpitations or difficulty relaxing; and by a question of in what extent they are agree or disagree with the statement that they work under a great deal of tension).

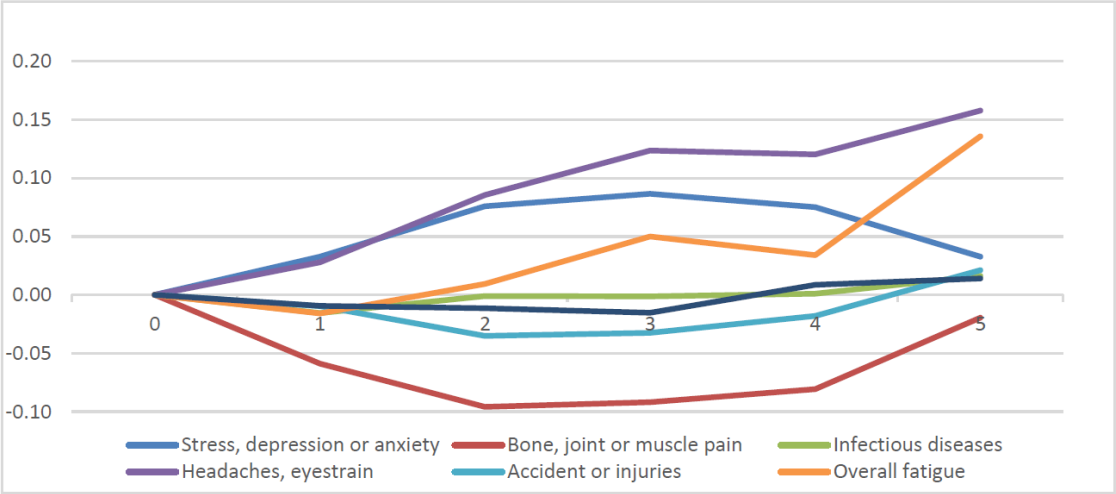
Figure 29. Predicted level of stress by degree of ALMA



Source: Jensen et al. (2024, p. 40)

More evidence about key outcomes related to OSH, appears in the statistical analysis of EU-OSHA report, which applies the same statistical method (OLS), associating ALMA and health issues in this case, which «differently from the psychosocial risk indicator that captures the perceived risk factors (…) the health outcomes indicator reports about health issues that have already occurred» (Pesole, 2023, p. 20). This specific statistical analysis shows that more intense use of ALMA (more surveillance or algorithmic management practices) increases OSH problems by 0.165 (including reported stress, depression or anxiety; bone, joint or muscle pain; infectious disease; headaches or eyestrain; accidents or injuries; and overall fatigue). Namely, when the ALMA index increases by one time, the OSH problems index increases by 16.5%.

Figure 30. Health issues by degree of digital technology adoption



Source: Pesole (2023, p. 15)

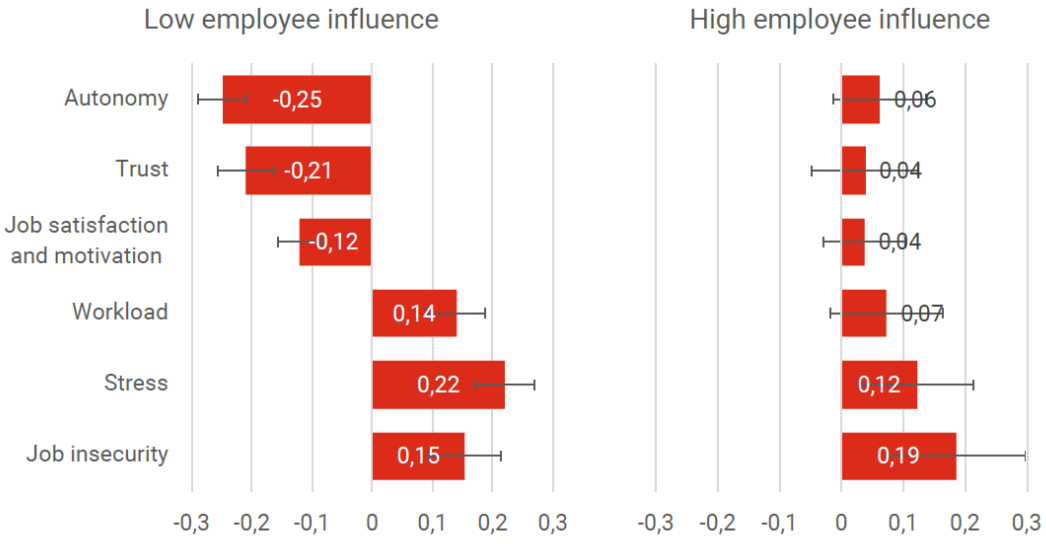
The highlighted results of the statistical analysis between ALMA and health issues could also be related to the corroborated consequences of increased digital technology adoption, such as headaches or eyestrain, overall fatigue, stress, depression or anxiety (see *Figure 30*).

Another outcome was that potential solutions were recommended to divert the OSH risks (in line with the findings described in *section 4.2.2* concerning qualitative studies in regular work or the following part of this subsection about moderators). Increasing transparency, and consulting workers when ALMA is implementing, are crucial as preventive measures. Moreover, the report argues that intrusive surveillance or data-driven management practices need proper regulation and comprehensive rules on ALMA should be a key policy focus (Pesole, 2023).

4) Moderators of the ALMA impact on psychosocial factors and OSH implications

As an additional aspect to consider compared to other evidence-based selected publications, the quantitative studies in regular work that were analysed also show the need to take into account some moderating factors. Regarding this issue, the previously described statistical analysis of the survey conducted in Nordic countries highlights the importance of worker participation, the also so-called in the academic literature the employee or "human influence" (see *sections 2.1* and *2.2* of this report), but additionally shows the relevance of transparency in enterprises (equivalent results to those previously pointed out in Pesole, 2023).

Figure 31. Estimated effects of ALMA by degree of employee influence (participation)

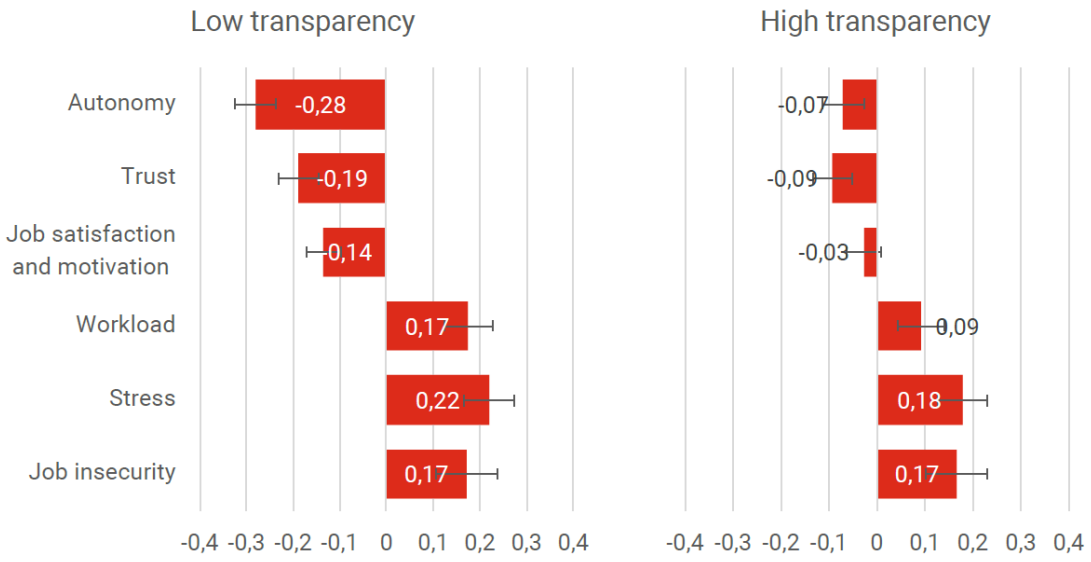


Source: Jensen et al. (2024, p. 44)

On the one hand, in the same study the "employee influence" was measured by questions that can be considered as worker participation in decision-making ("How much influence do you and your colleagues generally have on company decisions that influence the way you do your job?" and "To what extent are employees involved and consulted when the company decides to implement new computer systems that affect your work?"). Dividing into low and high levels of employee (or human) influence (i.e., worker participation), the statistical analysis shows that a deeper participation in decision making changes the trend of the ALMA impact on job resources, to the extent that ALMA does not reduce autonomy, trust or satisfaction and motivation in this condition, showing on the contrary a little improve in these job resources. However, job insecurity is worse compared with those who declare low participation in the decision-making process. Nevertheless, high employee influence/participation also reduces the negative impact on job demands (workload) and the experience of work-related stress (*Figure 31*).

Another important moderator is transparency. As the Nordic countries study verifies, even general management transparency in the enterprise (measured by the question: "Management decisions that affect me are always explained and communicated clearly") reduces the impact of ALMA. Although with a lesser moderator effect compared to the employee influence, transparency reduces the ALMA's negative impact on job autonomy, and moderates it on job demands and pressures, particularly in workload, but also buffers stress (*Figure 32*).

Figure 32. Estimated effects of ALMA at different levels of company transparency



Source: Jensen et al. (2024, p. 46)

The previous findings are in line with the results of another selected new evidence-based paper, which demonstrates that an increase in transparency moderates the impact of undesirable outcomes. Bujold et al. (2022) assessed truck drivers, observing the relationship between transparency of ALMA, distributive and procedural justice perception, and the workers' intention to quit their jobs (which can be considered as an indicator of a lack of well-being, motivation or engagement). Of the 110 respondents that are included in this study, the transparency of ALMA surveillance was positively related to procedural justice, whereas the transparency of algorithmic performance management was positively related to distributive justice. Both types of perceived justice (procedural and distributive) are negatively related to the intention to quit the job. As the authors concluded, «within the trucking industry, whether in the use of algorithmic surveillance systems (…) organisations will benefit from increasing transparency about what is being track», but also «if these organisations are using this data to feed an algorithmic performance management system, they will benefit from being transparent about how these systems are being used» (Bujold et al, 2022, p. 8). Namely, the transparency in two specific functions in ALMA ("monitoring" and "performance ratings") could have an indirect effect on OSH outcomes, as both can lead to a higher perceived justice among workers and, therefore, to a lower intention to quit. This indicates a higher motivation or level of well-being in the workplace, or at least more engagement to continue with their jobs.

4.2. Empirical qualitative studies on ALMA to delve into OSH implications

As in the previous section, all the papers gathered, using in this case qualitative methods (ethnographic study, interviews, case study), were divided by the type of work domain in which ALMA occurs, either on platform work (*subsection 4.2.1*) or in regular work (*subsection 4.2.2*).

4.2.1. Qualitative studies on ALMA in platform work

Paula Lara (INSST, Spain), Thomas Strobach (AUVA, Austria), Joanna Kamińska (CIOP-PIB, Poland) & Fabio Boccuni (INAIL, Italy)

Among the scientific articles, 15 studies have used qualitative research methods to delve into ALMA in platform work, almost half of all selected publications of the scientific literature review. These studies include the following research methods: interviews, focus groups, observation and content analysis. Indeed, some of the selected articles conducted both quantitative and qualitative techniques. In this section, the focus is on the empirical qualitative evidence on psychosocial factors or OSH implications in the platform work domain. The methodological tools, as well as the sample design and size, are a wide range among these scientific studies. One of the most used qualitative techniques has been the interview. This tool is present in most of the selected studies in different formats and styles. Other studies included focus groups, ethnographic analysis, and data collection from messaging applications and online posts. Also, sample sizes vary across the studies, mainly because of the attempt to search for saturation instead of statistical representation. As a result, the scientific literature reviewed for this section uses an amalgam of qualitative techniques that allow us to explore the effects of ALMA in the platform work domain. In particular, most of the selected articles are centered on food and groceries delivery workers, ride-hailing and truck drivers.

As previously underlined in other sections, ALMA can restructure workflows, enhance efficiency and sometimes foster positive job resources (e.g., better coordination, autonomy, etc.), but it also can impose higher demands. As documented across Europe, China, the Philippines, Brazil and North America, these demands may lead to stress, burnout, harassment and other psychosocial risks if not effectively mitigated by governance, human oversight, fairness mechanisms or other protective factors.

The main findings of the mentioned publications are presented, as in the previous section, in the following order: results between the evidence on job demands and psychosocial pressures, job resources and potential benefits, and key corroborated outcomes for OSH.

1) Job Demands and Psychosocial Pressures

A recurring theme is that algorithmic systems may intensify job demands, particularly regarding workload, time pressure, performance pressure and uncertainty. Regarding **time pressure and performance demands**, several authors emphasise how ALMA can heighten the speed and frequency of tasks. For instance, some Uber drivers, when interviewed, point out how the algorithm “pushed” them to be connected to the platform almost permanently. Some of these workers perceive that their actions could "anger” the algorithm, also showing the lack of action control at work (Riesgo, 2023). Similarly, Cañedo and Allen-Perkins (2023) observe from their interviews that some platform workers in “food-delivery” try to serve as many clients as possible, following the pace imposed by the platform's algorithms, which could result in exhausting workdays. Other authors, such as Huang (2022), point out how “riders in food-delivery” perceive that time pressure is enhanced by the algorithms on the platform, which generate stress. Also, the performance demand is a key point because workers feel that they must fulfill all the client´s demands. Wu et al. (2023) report how ALMA affects the service behaviors of food delivery platform workers, underlining both improvements in efficiency and extra-role duties to please customers. Similarly, Tuomi et al. (2023) examine Wolt and Foodora couriers and find that algorithmic control enforces strict performance standards, intensifying the pace of work and reducing autonomy, leading to psychosocial strain. Maffie (2024) analyses how “Instantcart Shoppers” are incentivised to move quickly, often leading to tensions with in-store employees and creating an environment fraught with stress.

Many authors analyse how **platform workers feel stressed** by their jobs. For instance, Soriano (2024) emphasises how “riders in food-delivery” perceived that they are continuously been monitored by the platform's algorithms. Similarly, some Uber workers perceive that they are constantly overloaded due to the difficulty in disconnecting from the platform, leading to stress (Riesgo, 2023). Other authors, as Cañedo and Allen-Perkins (2023), have detected that platform workers perceive that they bear a great amount of work, increasing stress in some workers. Huang (2022) describes a similar experience from platform workers in China and Wu et al. (2023) reported that Chinese food delivery platform workers often feel treated like robots, with unified service standards and real-time surveillance, showing how algorithmic management can lead to

stress and burnout. Also, Zhang et al. (2022) report how ALMA negatively affects the **psychological well-being** of "gig economy" workers, highlighting issues of information asymmetry and manipulative incentives that contribute to the feeling of being exploited. Nevertheless, point out that by promoting a participatory approach, platform workers themselves can co-design solutions such as information translucency, co-configured incentives, well-being-centered data analytics and collective information sharing, which may improve their experience and well-being at work. Lu et al. (2024) report that high ALMA levels lead to stress, particularly when human intervention is minimal. Algorithmic systems are perceived as unfair or overly rigid, prompting coping strategies such as taking additional jobs to offset income loss. It seems that **excessive workload** and stress remain a pattern that repeats among most of the regions analysed in the selected articles, regardless of the platform work-specific sector.

Other consequences have been described from the studies review, for instance, Möhlmann et al. (2023) introduce the concept of "algorithm sensemaking", where drivers feel reduced to metrics and experience a loss of autonomy and meaning, or dehumanisation and "datafication" in the terms of the EU-OSHA (*section 3.2*). Workers perceive decisions as opaque and often struggle to interpret algorithmic logic, contributing to a sense of insecurity and **depersonalisation** (Möhlmann et al., 2023).

2) Job Resources and Potential Benefits

ALMA monitoring is perceived by some workers as a beneficial tool for their personal **safety** while driving, which could lead to a reduction of stress levels (Soriano, 2024). Also, any deliverers were willing to comply with algorithmic rules, especially those about transportation safety, because they believed them to be reasonable (Wu et al., 2023)

Ramesh et al. (2023) show that an application for personal shoppers (customers can order groceries) can lead to positive activation and **autonomy** in addition to negative effects (ambivalence, feelings of insecurity, frustration and anger). However, there is a risk that the design of the system through ludification could manipulate the click worker by faking characteristics of autonomy (Ramesh et al. 2023).

Also, Lu et al. (2024) suggest that when ALMA-AI was perceived as a challenge, workers emphasised the importance of delivering high-quality service to navigate and overcome algorithmic constraints. These findings highlight the **dual role of algorithmic management** as

both a stressor and a motivator, underscoring also the importance of **human oversight** in maintaining worker well-being and engagement in platform-based labour.

Similarly, Tuomi et al. (2023) document how workers develop “algorithmic competencies” to navigate or resist algorithmic rules, for example, by finding loopholes or selectively complying with acts of resistance termed "algoactivism."

3) Key Outcomes for Occupational Safety and Health (OSH)

Regarding the qualitative evidence on OSH implications, although not all selected studies focus explicitly on accidents or physical hazards, these studies identify potential psychosocial and mental health consequences:

- **Stress, Burnout, and Reduced Meaningfulness.**

Several studies (Ramesh et al., 2023; Cañedo & Allen-Perkins, 2023; Wu et al., 2023; Soriano, 2024) suggest that algorithmic controls can yield elevated stress levels, especially when decisions feel opaque, metrics-driven, or unfair.

- **Engagement vs. Disengagement**

Zhang et al. (2022) highlight that the incentives from gamification systems can make drivers more efficient, work harder, and attract new and former drivers to the platform. However, the gamification of their profession makes drivers feel like they work in an unequal and unfair system, a system with unclear rewards and objectives.

- **Potential Spillover Effects**

In the grocery delivery context, Maffie (2024) underscores how pressures placed on gig workers can spill over to conventional employees, exacerbating workplace tensions. This finding raises the possibility that algorithmic pressures do not only affect immediate platform workers but can alter the broader work environment, with implications for collective well-being and safety. Granulo et al. (2024) demonstrates how deploying algorithms in management tasks affects the prosocial motivation of workers and negative effects extend beyond individual consequences and can influence the social dynamics. Also, Zhang et al. (2022) report the social isolation of gig platform drivers often working alone, without social support or interaction with other workers.

- **Physical safety/Autonomy**

The drivers of gig-work platforms shared concerns over their physical safety and possible carjackings when they work in unsafe neighborhoods. The physical safety of drivers concerns also to the exhaustion that accompanies long hours of driving (Zhang et al., 2022). The results of Maschio et al. (2023) show a new type of moderating factor, namely the alternatives that these workers have in the labour market — included in the ERI model as "dependency" circumstance and in the ALMA-AI project approach as a "contextual moderator" —, which can influence the perceived resources or rewards of workers. However, as the employment alternatives are perceived as worse in terms of financial compensation or salary and autonomy in choosing working hours, delivery workers tend to see this job as offering more autonomy and rewards. These perceptions can have important implications for occupational safety, as they have even led to the risks of this type of ALMA being disregarded by workers (Maschio et al., 2023)

Conversely, Tuomi et al. (2023) demonstrate how algorithmic scheduling, monitoring, and goal setting diminish real autonomy by enforcing rigid workflows and reducing opportunities for discretion. Food delivery couriers report that algorithmic management shapes every aspect of their tasks —from navigation to timing— limiting their ability to exercise agency. Similarly, Möhlmann et al. (2023) show that perceived lack of transparency and unpredictability in algorithmic decisions reduce workers' control and undermine their sense of autonomy. Drivers attempt to interpret and "make sense" of these opaque systems through "algorithm sensemaking," often reacting strategically but without real power to influence outcomes.

4.2.1. Case studies on ALMA in regular work and specific sectors

Denis Losada, Jon Zubizarreta (INSST, Spain), Marie Jelenko (AUVA, Austria), Karolina Pawłowska & Katarzyna Hildt (CIOP-PIB, Poland)

This subsection analyses the results from a variety of studies that have addressed, from a qualitative methodology, the effects of ALMA on different regular work environments. Most of them constitute case studies, allowing for a more detailed picture of the role of ALMA in diverse work organisations. One of the main conclusions from this section of the review is the idea that the implications of ALMA for OSH are highly context-dependent (Pesole & Cetrulo, 2024).

1) Job Demands and Psychosocial Pressures

The review of the selected articles and studies highlights higher job demands derived from ALMA, especially through higher skills requirements and the intensification of (qualified) work.

- **Work intensification and impact on skills**

Whereas work intensification varies among the reviewed articles and studies, the influence of ALMA on working skills seems clear from different perspectives. Companies tend to need more qualified workers, running into the need to train them both in technical issues and in new ways of communicating (Pesole & Cetrulo, 2024; Rani, Pesole & González, 2024). This aspect becomes problematic when it produces bigger workloads or a higher work intensification, as in the case of the Belgian automotive company (Gillis, 2024). Furthermore, work intensification is also closely related to the monitoring possibilities of ALMA, as reported by Indian and South African workers (Rani, Pesole & González, 2024). Employee supervision is therefore enhanced in those contexts, getting to the point of monitoring their breaks or producing pressure to maintain a certain level of work.

2) Job Resources and Potential Benefits

- **Lack of autonomy**

A case study conducted by EU-OSHA at a Belgian automotive manufacturing company that has implemented ALMA underlines the fact that operators working at the assembly line have little to no autonomy (Gillis, 2024) as tasks are strictly timed and monitored by the ALMA system. As a result, work also becomes highly repetitive. On the other hand, the Rani, Pesole and González *(*2024) compilation of case studies also recollects the experience of healthcare and logistics workers regarding autonomy in companies from South Africa, India, Italy and France. In

the Italian and French cases, the authors assume that the provided task guidance clearly limits workers' autonomy, although none of them reported such a problem. However, the interviewed South African workers did express their frustration due to the lack of ability to make decisions (Rani, Pesole & González, 2024).

- **Poorer social relations and work-life balance**

In the Belgian automotive company, probably due to work intensification, workers reported little to no time for social interaction, as well as difficulties managing their stress outside working hours (Pesole & Cetrulo, 2024). The South African private hospital workers expressed a significant worsening of their social relations after the integration of ALMA, especially towards managers, as they felt that bigger monitoring as well as being blamed for misunderstood mistakes (Rani, Pesole & González, 2024).

Despite the psychosocial costs that were described above, some of the case studies within this section constitute good examples of how ALMA, if properly applied, can also produce a variety of benefits regarding the increase of job resources:

- **Benefits from monitoring**

Team leaders from the Belgian automotive company (Gillis, 2024) reported clear advantages in their working conditions due to the technical possibilities of ALMA. For instance, it allowed for real-time status updates from every workstation, resulting in time efficiencies, better performances, and therefore a bigger sense of control of the workflow. Workers at all levels also claimed that monitoring offered an objective standard of evaluation of their work that helped in their performance.

- **Greater work efficiency**

Workers from companies such as the Italian automotive firm studied by Annarosa Pesole and Armanda Cetrulo (2024) appreciated the access to the comprehensive process information and the more flexible task structure facilitated by ALMA. In this way, despite the stringent quality controls that manage the production process, there is evidence of some autonomy and discretionary management of daily tasks. Similarly, the ALMA systems from the logistics companies studied by Uma Rani, Annarosa Pesole, and Ignacio González (2024) allowed certain labor-intensive tasks to be performed by technology, which gave employees more time to perform other tasks, as well as contributed to streamlining monotonous tasks.

- **Improved social relations**

Contrary to what was reported by people from the South African private hospital (Rani, Pesole & González, 2024) or the Belgium automotive company (Gillis, 2024), the interviewed workers from the Italian automative firm described an improved better environment after the integration of ALMA, characterised by better communication and fewer conflicts (Gillis, 2024; Pesole & Cetrulo, 2024). Curiously, the Italian hospitals studied by Rani, Pesole and González *(*2024) also reported their positive impact *on* cooperation and communication among workers. Taking all reviewed cases into account, social relations seem to accompany the overall psychosocial context of each company, contributing to the idea that the implications of ALMA for OSH are highly context-dependent (Pesole & Cetrulo, 2024).

3) Key Outcomes for Occupational Safety and Health (OSH)

The reviewed studies didn't quite focus on the specific outcomes for OSH originated by the integration of ALMA in the different case studies. The EU-OSHA studies (Pesole & Cetrulo, 2024) did address some of the main effects from the Belgium and Italy automative contexts, comparing the outcomes from a properly applied ALMA system (as in the Italian firm) with one that clearly produces a variety of psychosocial pressures (as in the Belgian case). Thus, the following outcomes have been pretty much obtained from those case studies, regardless of the usual psychosocial effects that can likely be produced from all the previously described contexts.

- **Negative outcomes**

Mainly found in the Belgian automotive company (Pesole & Cetrulo, 2024): cognitive stress, anxiety, depression, and other mental health issues related to high workloads, the intensification of work, and the lack of autonomy. Besides, it's important to point out further consequences such as isolation, work-like conflicts, or the bigger risk of accidents and errors.

- **Positive outcomes**

Mainly found in the Italian automotive firm (Pesole & Cetrulo, 2024), specifically, mental and cognitive wellbeing, upskilling (as workers have time for training or enriching individual portfolios), innovation and engagement. Finally, the interviewed logistics employees in Italy (Rani, Pesole & González, 2024) indicated that the introduction of ALMA solutions improved working conditions and reduced physical strain, producing lower levels of stress and fatigue.

4) Preventive Measures and Participatory Approaches

ALMA-AI technologies can be beneficial for detecting and preventing psychosocial risk factors, but they may also exacerbate some of these risks, particularly those related to worker surveillance and performance assessment. To ensure that the benefits outweigh the potential downsides, it is essential to equip worker representation structures with the ability to access and negotiate the algorithms behind these technologies effectively.

For example, the use of remote monitoring and performance evaluations through ALMA systems could reduce workplace autonomy and infringe upon workers' privacy and discretion. In a comparative case study of two large-unionised ICT companies in Germany and Norway, Doellgast et al. (2022) highlight that well-established collective bargaining processes can be pivotal in limiting the use of employee data and safeguarding against invasive technologies, such as speech analysis.

However, for collective bargaining to effectively secure favourable working conditions, it is crucial to account for variations in national institutional frameworks and customs. For instance, in the healthcare sector, implementations of ALMA-AI systems have had varying results depending on the country where they were carried out. In two cases in Europe, Italy and France, despite the absence of a structured consultation with workers, it doesn’t seem that this led to a lack of trust in the organisation or generated conflict. However, in another case in South Africa and India, consultations did take place, but more for cosmetic purposes and with no real impact on the development of the technology (Rani, Pesole & González, 2024).

Another approach to enhancing ALMA is the inclusion of workers in the development process of applications used for worker management. Spektor et al. (2023) conducted a qualitative study examining an existing ALMA app used in hotels to coordinate guest room attendants. The study employed workshops, in-depth interviews, and interactive sessions to create a human-centered app, focusing particularly on workload, self-efficacy and transparency. From the workers’ perspective, the ideal design of such an application struck a balance between the rewarding aspects of their work and the pressures of their workload. Nevertheless, the study also demonstrated that technological design alone cannot address all the challenges posed by ALMA.

Overall, it can be stated that institutional capacities give employees and their representatives the right to be informed and/or consulted about the introduction and implementation of ALMA. However, institutional capacity alone is not sufficient to ensure that employee representation can fully exercise these rights. To do this effectively, workers and their representatives need the technical knowledge required to monitor the use of ALMA-AI and to participate in negotiations on implementation (Molina et al., 2024). Nevertheless, other OSH risks are listed, such as the "datafication" and dehumanisation of workers, their privacy, discrimination issues, power imbalances and technical malfunctions, also highlighting opportunities, such as the real-time monitoring of OSH or physical and mental well-being.

V. CONCLUSIONS AND DISCUSSION

Jorge Martín (INSST, Spain)

5.1. Prevalence of ALMA and previous research findings on OSH

The **phenomenon of Algorithmic Management (ALMA) is increasing**. Only six years ago, the ESENER-3 survey conducted by the EU-OSHA showed that, on average, 11% to 15% of European enterprises used digital technologies for worker management (Christenko et al., 2022a). Nowadays, as the survey gathered by the OECD highlights, between 35% and 70% of companies in Europe declare they use at least one tool of ALMA for monitoring, giving instructions or evaluating workers (Milanez et al., 2025). By sector, although experts have pointed out that ALMA is present especially in logistics, manufacturing, transport and healthcare (Christenko, Jankauskaitė & Paliokaitė, 2022), other surveys identified other sectors, such as high technology and knowledge-intensive services, public administration or education (Fernández-Macías et al., 2023), but also warehouses, marketing, retail, aviation or financial services (Jensen et al., 2024).

However, it is important to acknowledge that some collected data on ALMA may not precisely reflect the expansion of this new form of work organisation. To better capture this phenomenon, it is likely more relevant to **focus on jobs or workplaces that used ALMA intensively** or "strongly" (e.g., a minimum of four uses or tools), or at least focus on those "soft platformised" (e.g., two uses of ALMA or digital monitoring), as categorised by the JRC´s authors of the AMPWork survey (Fernández-Macías et al., 2023). This point could be crucial for accurately assessing ALMA expansion, because some survey questions about its uses or tools may encompass management functions that have been digitalised for years, which do not need complex systems. For instance, one of the highest prevalences of ALMA´s use is to monitor working time (44% of European enterprises in 2025), being even a legal obligation in some countries (like Spain, where companies must digitally record employees' working hours). This type of distinction could be important for accurately **measuring ALMA prevalence**. For example, data from Germany and Spain in 2022 indicated that 10% and 18%, respectively, were "soft platformised" workers, although only 1.3% to 6.1% were "strongly" organised or monitored by algorithms or AI (Fernández-Macías et al., 2023). Conversely, as previously mentioned, the recent survey by the OECD (Milanez et al., 2025) reported significantly higher percentages of specific uses of ALMA in these European countries (around 35% to 70%), but considering only at least one tool or use, measure that could be interpreted as an overestimation of the phenomenon.

Otherwise, concerning **OSH implications**, cutting-edge institutions (EU-OSHA, JRC and ILO) gathered previous evidence about risks and opportunities of ALMA (until 2022), reflecting the importance of the so-called **psychosocial factors** (those conditions related to work organisation and social relationships at work that can harm workers and impact their safety and health).

On the one hand, the EU-OSHA highlights several OSH risks, which are psychosocial factors by definition, for instance, in the well-known **Demand-Control-Support (DCS)** model to manage stress at work, developed initially by Karasek (1979). Primarily, the **EU-OSHA´s research** underlines the impact of AI for worker management through an intensification of work (clearly a high "demand"), the lack of autonomy or "control", and the probability of social isolation (plainly a lack of social "support"). Nevertheless, it also listed other risks related to ALMA, such as the "datafication" and dehumanisation of workers, ethical issues regarding the power imbalances, those linked to fundamental rights affected by data processing (personal privacy or non-discrimination) or those resulting from technical malfunctions (Reinhold et al., 2022).

On the other hand, the **JRC and ILO research** pointed out the importance of some factors that are increasing through the introduction of ALMA practices in regular workplaces, affecting the "job quality" (Baiocco et al., 2022) with the presence of some mentioned concepts of the DCS model, but also, from the **Effort-Reward Imbalance (ERI)** model, elaborated by Siegrist (1996). The JRC and ILO have identified as key effects of ALMA the work intensification or a worsening of working time (higher demand or "effort"), but also the detriments to the social environment, autonomy and job security in enterprises that use algorithms or AI-based systems to manage workers (boosting both a lack of control and social support in the lens of the DCS model, but also reducing the socio-emotional "rewards" by the ERI model perspective).

Additionally, considering the **Job Demands-Resources (JD-R)** theoretical model, originally developed by Demerouti et al. (2001) and assumed by relevant authors in the field of algorithmic management (Parent-Rocheleau & Parker, 2022) – also by the ALMA-AI project – all the highlighted (psychosocial) risk factors in the cutting-edge **previous research until 2022** (Reinhold et al., 2022; Baiocco et al., 2022) reflect an imbalance between higher job demands (work intensification, working hours) and resources constraints to deal with them (lesser autonomy, lack of social support or job insecurity), which would increase the **likelihood of experiencing negative OSH consequences** (stress, burnout or harassment) instead of positive outcomes (engagement, motivation or well-being) in those traditional workplaces that used ALMA.

Furthermore, the **"health impairment process"** assumption of the JD-R model (job demands that surpass workers resources, creating OSH problems) **match with the previous evidence** gathered by cutting-edge institutions, but also with **literature reviews** focused on the more studied domain of **platform work** (Vignola et al., 2023; Felix et al., 2023). It is necessary to reinforce that the field in which AI for worker management had its origins, and in which ALMA is nowadays certainly widespread, corresponds to this domain, also known as the gig economy. However, it is important to consider that only a **small proportion of employees** in the labour market can be considered as platform workers, as only 1.4% to 2.3% of the workforce use this job as the main source of employment (Urzi et al., 2020; Fernández-Macías et al., 2023). The cited literature reviews on platform work that covered until 2022, verified that ALMA increases **job demands** throughout an intensification of workload, especially with **time pressures** for platform workers, generating mental health issues (anxiety, emotional exhaustion or stress), but also unsafe behaviours (Vignola et al., 2023). Additionally, ALMA affects platform workers' **resources**, **restraining autonomy and, especially, job security**, propelling unstable incomes and a lack of schedule stability, benefits or social protection (Vignola et al., 2023; Felix et al., 2023).

However, the particularities of platform work – e.g. platform workers assumed as freelance – can also intensify the mentioned factors, and ALMA in this specific domain affect workers in other ways, for instance, creating a **loss of meaning**, but also propelling **asymmetries in information and power** or **a lack of transparency** (Felix et al., 2023), being this last one an example of **"socio-technical" factor** (Parent-Rocheleau & Parker, 2022). Continuing with other factors beyond psychosocial ones, in the ALMA-AI theoretical approach, it is also pointed out the influence of **"individual moderators"**, such as the workers´ preferences, for instance, for autonomy, which can increase the likelihood of well-being when fit with the operational model, or values, in platform work (Felix et al., 2023). Therefore, this individual preference (for autonomy rather than for more job security) could buffer the imbalance between psychosocial factors (job demands *vs* resources) associated with ALMA effects, but it may also increase it (with a dealignment between individual preferences and organisational practices). Additionally, it is highlighted other **"contextual moderators"** that can influence the ALMA effects, such as other sources of income beyond platform work (Vignola et al., 2023) that could be considered as a partial alternative in the labour market, reducing dependency (in terms of the ERI model), and which could buffer negative impacts of ALMA generated by psychosocial factors imbalance.

5.2. New evidence on ALMA: Psychosocial risks and OSH missing opportunities

An important conclusion of the evidence-based ALMA-AI project literature review is that the **present use of ALMA usually generates excessive job demands and limits workers' resources** to deal with them. Furthermore, several studies show the association between ALMA and **negative OSH implications**, especially throughout an **intensification of psychosocial risks**, such as stress, burnout, harassment or violence, that can boost different health issues (e.g., anxiety, depression, fatigue, accidents or injuries). Even though there is a growing interest in the scientific literature to identify potential positive effects of ALMA (such as motivation, engagement or well-being), the statistical analyses conducted with representative samples capture another reality.

Firstly, research consistently demonstrates that the **psychosocial pressures** associated with the current application of ALMA contribute to working conditions that heighten the probability of experiencing OSH risks. This general finding is supported by the convergence of results from both quantitative and qualitative research methods, across platform work and regular jobs.

In quantitative analyses of platform work, numerous studies confirm that ALMA leads to psychosocial pressures that increase the level of work-related stress (Lu et al., 2024; Hajiheydari & Delgosha, 2024; van Zoonen et al., 2023; 2024). This is further corroborated by some multivariate data analysis, which indicates that a crucial job demand propelled by ALMA in the platform work domain is **time pressure** (Semujanga & Parent-Rocheleau, 2024).

The time pressure as job demand has also been extensively documented in qualitative research that delves into platform workers' experiences through interviews or ethnographic studies. These studies frequently identify an **excessive workload** as a pattern of ALMA, irrespective of the specific platform work sector (Huang, 2022; Cañada & Allen-Perkins, 2023; Riesgo, 2023; Soriano, 2023; Tuomi et al., 2023; Wu et al., 2023). Qualitative findings refer to this high level of job demands as “overload” (Riesgo, 2023), “great amount of work” (Cañada & Allen-Perkins, 2023) or even a feeling of “being exploited” (Zhang et al., 2022).

Additionally, case studies conducted by EU-OSHA, JRC and ILO illustrate how ALMA can influence traditional workplaces, highlighting the critical **need for qualification**, which becomes problematic when it heightens the existing workload (Guillis, 2024). Moreover, in some contexts, the **intensification of work** appears to be **directly related to monitoring** (Rani, Pesole & González, 2024), a specific function in the selected model of the ALMA-AI project.

Secondly, new evidence gathered by the ALMA-AI project also suggests that the observed association between ALMA and its negative OSH outcomes may be further reinforced by **restricting workers' resources**, particularly when ALMA is used as a control mechanism. Both in platform work and regular jobs, various algorithmic functions constrain well-known psychosocial factors, as control or social support (key elements in the DCS model). For example, studies in platform work demonstrate that specific ALMA functions, like monitoring, scheduling and goal setting, establish rigid workflows and reduce opportunities for workers' discretion (Tuomi et al., 2023). This notably affects their **autonomy**, especially when they perceive algorithms as opaque (Möhlam et al., 2023). In traditional workplaces, specific contexts, such as automotive factories, use ALMA for strictly timed and monitored tasks, leading operators to experience little or no autonomy (Guillis, 2024). Furthermore, analyses of other case studies in diverse sectors (healthcare and logistics) reveal workers' frustration over a lack of voice in decision-making, simultaneously limiting their time for **social interaction** (Rani, Pesole & González, 2024).

The highlighted findings, by illustrating the impact of different ALMA functions in restraining workers´ resources, also suggest that OSH negative effects, as previously discussed regarding ALMA prevalence, are likely associated with the **intensive use of ALMA** or those work environments “strongly platformised”, in terms of the JRC team (Fernández-Macías et al., 2023). For instance, the simultaneous application of algorithms or AI for distributing work schedules, allocating activities and monitoring task completion, both in platform work and regular jobs, can contribute to undesirable effects for OSH.

Significantly, the most robust evidence for the association between ALMA intensity and negative OSH implications stems from statistical analyses of more extensive and representative European samples, which unequivocally demonstrate that wider ALMA use intensifies the **probability of psychosocial risks**. Specifically, the surveys carried out by EU-OSHA gathered essential data, which were used to corroborate this association. Previously, the ESENER-3 multivariate statistical analysis, based on the responses of employers, managers or staff responsible for OSH of 45,420 enterprises in 33 European countries in 2019, pioneering corroborated that the use of technologies for management (e.g., monitoring and determining the pace or content of work) increase the probability of psychosocial risks, measure by an index in which excessive job demands (time pressure and long working hours) and also low worker´s resources (poor communication or fear of job loss) were included (Urzi & Curtarelli, 2021).

However, the new evidence regarding the ALMA's impact on psychosocial risks is drawn from the OSH Pulse survey, conducted in 2022 with a sample of 27,250 workers across the 27 EU countries. Using this EU-OSHA dataset, it has been shown, once again, that **ALMA intensity correlates with** a higher incidence of psychosocial risks in the workplace and a greater prevalence of workers' health problems. This conclusion emerges from the OSH Pulse statistical analysis, revealing an **increase of 21% in psychosocial risks and 16.5% in health issues** when the intensity of ALMA rises by one unit (Pesole, 2023). This type of ALMA "organisational model" was operationalised as a cumulative index of several of its uses (determine pace of work, increase surveillance, supervise or monitor work, allocate tasks or schedules), consider in this occasion the psychosocial index not only excessive job demands and limited resources, but additionally psychosocial risks *per se* (bullying, harassment, violence or other sources of stress). The measure of health issues was also a cumulative index constructed by workers reporting OSH issues in the past three months, such as stress, anxiety and depression, but also musculoskeletal disorders, infectious diseases, headaches, overall fatigue, accidents or injuries (Pesole, 2023).

Another important piece of evidence identified by the ALMA-AI project is provided by a survey of 5,141 workers, conducted in 2023 across Nordic countries by several foundations, spearheaded by FEPS (Jensen et al., 2024). Their statistical analysis reveals a clear impact of ALMA on job demands and resources. On one hand, as the intensity of algorithmic or AI use to manage workers increases, there is a higher probability of excessive workload. On the other hand, when ALMA use is more intense, a decrease in autonomy and job security is also observed. However, the most significant evidence from the statistical analysis of the Nordic dataset is that the **intensive use of ALMA almost doubles the stress level** compared to workplaces that do not apply algorithms or AI for worker management. When ALMA is absent (intensity equals 0), the stress level is 0.35 (on a scale between 0 and 1 constructed by a combination of workers' self-reported symptoms of elevated stress in the past months and the assertion that they work under a great deal of tension). In contrast, when ALMA is used intensively, reaching the maximum level of its cumulative index (equal to 1, which shows ALMA is used simultaneously for monitoring, goal setting, scheduling, and performance rating), stress levels rise to 0.58 (Jensen et al., 2024).

Thus, while numerous qualitative studies conducted between 2022 and 2024 reveal the psychosocial pressures imposed by ALMA and the consequent risks experienced by workers (such as stress or burnout), multivariate statistical analysis of extensive samples in European

countries provides the most compelling evidence. This more representative overview, based on surveys of both employers and workers, corroborates that **ALMA intensity increases the probability of negative OSH implications**, intensifying psychosocial risks and health issues.

Furthermore, the undesirable consequences of ALMA are also verified in other extensive samples and some relevant quantitative studies that focused on its **potential positive outcomes**. On the one hand, the development of a validated 'Algorithmic Management Questionnaire' (AMQ) with over 1,330 platform workers in North America, additionally corroborates that more **intensive ALMA** is associated with **lower autonomy and task complexity**, which indirectly **contribute to lower work engagement** (Parent-Rocheleau et al., 2024). On the other hand, the dataset of the European Company Survey in 2019, conducted by two EU agencies (Eurofound and Cedefop) across 21,869 enterprises, was used to delve into the association between ALMA practices and workplace well-being, corroborating an inverse relationship (Kinowska & Sienkiewicz, 2023). When ALMA is more prevalent, **well-being decreases**, albeit with a small effect. However, the impact **particularly** intensifies **when ALMA reduces autonomy**.

In summary, most of the **new evidence gathered by the ALMA-AI project** from 2022 to 2024 reinforces previous findings from both the scientific and grey literature. The intensity of ALMA, as a new form of work organisation, is contributing clearly to **negative OSH implications**. Specifically, in its current implementation, ALMA simultaneously **exacerbates psychosocial risks and health issues throughout an intensification of job demands** (e.g., work overload and excessive time pressures) while also **reducing well-being and engagement by restricting workers' job resources** (e.g., autonomy and social support).

Nevertheless, another significant outcome of the aforementioned statistical analysis for the discussion is that **total rewards** (including economic incentives, but also stimulating work and professional development) constitute the **psychosocial factor that truly enhances well-being** (Kinowska & Sienkiewicz, 2023). This finding could need particular attention in future research, especially given that the same statistical analysis also indicates that ALMA does not particularly influence the rewards that workers perceive (Kinowska & Sienkiewicz, 2023). Specifically, it appears that **ALMA or AI-based systems**, that have been designed primarily to **improve productivity** (efficiency, costs, performance) — as highlighted in some patent studies (Staccioli & Virgillito, 2024) — have **not yet attracted workers through perceived rewards**, such as potential improved pay, more stimulating work, or better career development prospects.

5.3. How to improve ALMA? Assessment, moderators and preventive measures

Further research and case studies on ALMA are imperative to continue identifying effective preventive measures to ensure OSH, including the knowledge about factors that can operate as "moderators" to buffer negative effects (as mitigation measures). However, the development of specific assessments to capture the intensity, functions or uses of ALMA is a crucial first step. These measures should aim to quantify aspects of ALMA or AI-based systems that can create OSH risks, or also affect other fundamental rights (e.g., non-discrimination or privacy).

Regarding the **need for ALMA-related risk assessment** measures, several questions included in extensive and representative samples in Europe could serve as a suitable starting point for assessing ALMA's impact on companies. Examples are included in the EU-OSHA surveys related to the management function and the use of digital technologies involved (in ESENER[19] or OSH Pulse[20]), but also in other questionnaires included in their corresponding publications, such as the Nordic survey spearheaded by FEPS (Jensen et al., 2024) or the AMPWork survey conducted by JRC (Fernández-Macias et al., 2023)[21].

However, an accurate alternative to provide enterprises with high-quality assessments could be the development of psychometric scales or adapting existing ones. This approach can offer validated questionnaires, while also allowing for the calculation of the effects of ALMA intensity, functions or specific uses, additionally providing an opportunity for comparative research across different contexts and sectors. Specifically, the **'Algorithmic Management Questionnaire' (AMQ)** developed by Parent-Rocheleau, Parker, Bujold and Gaudet (2024) — whose specific items are included as Annex 1 of their scientific article — could be an ideal starting point throughout **its translation and validation in various countries**, proving a precise tool for enterprises to assess their exposure to ALMA. Additionally, validating this scale would help to corroborate the association between ALMA intensity (e.g., general score of AMQ) and negative

[19] ESENER-3 questions on "digital technologies at work" focused on machines, systems or computers that determine the content or pace of work, or monitoring workers' performance (`Data visualisation´ in link)

[20] OSH Pulse 2022 expanded the questions related to ALMA, not only about digital technologies determining speed or monitoring work, but also items about increasing workload, surveillance, reducing autonomy, resulting in working alone, automatically allocating shifts or tasks, or being rated by third parties (see questions A1 and A2 in OSH Pulse questionnaire, available in link)

[21] The AMPWork survey questionnaire is included as an Annex, considering eight items about monitoring within question B20 (p. 97) and eight more on other ALMA issues from questions B21 to B28 (p. 98)

OSH consequences (stress, emotional exhaustion, or health issues), corroborating the mediation of some (psychosocial) factors. It is noteworthy that the original AMQ validation only considered job autonomy and task complexity as factors to measure ALMA's impact, with engagement as an indirect positive outcome (although finally, the AMQ total score demonstrated a decreasing effect on engagement via lesser autonomy and complexity).

Nevertheless, careful attention should be paid to the **content validity of the AMQ scale** when used for translations to different realities. The scale was initially developed using platform workers as respondents. However, ALMA implemented in traditional workplaces or regular jobs often possesses pre-existing organisational structures that can significantly influence its effects (Baiocco et al., 2022). Furthermore, some items tested during the AMQ scale's development may not be appropriate for work environments beyond platform work. For instance, ALMA functions related to "compensation" might not determine the entirety of an employee's salary in regular employment. Another example highlighting the need for a proper content analysis of the AMQ involves ALMA uses that could significantly shape the employees´ future work. This includes uses like automatically allocating tasks or activities based on present performance ratings. While these are not strictly part of the "job termination" dimension (which was excluded from the final AMQ scale developed with platform workers due to its inadequacy in the confirmatory analysis), they could still affect OSH by intensifying psychosocial risks, such as stress.

Beyond the need for proper assessment, one of the most important conclusions of the ALMA-AI literature review is that **certain "moderators"** possess significant potential to buffer negative effects and can therefore **be considered as preventive or mitigation measures** to apply in enterprises that use ALMA, especially the involvement of workers and transparency in the design or operation of the algorithmic or AI-based systems for worker management.

Firstly, **worker involvement** refers to having a voice, control or participatory mechanisms regarding the design and/or operation of the ALMA system. In the scientific literature, this is often termed "human influence" and is categorised as a "socio-technical" moderator (Parent-Rocheleau & Parker, 2022), also in the ALMA-AI selected model. In the context of platform work, quantitative studies have demonstrated that human involvement **buffers psychosocial pressures** that exacerbate OSH risks (Lu et al., 2024). Furthermore, the degree of workers' involvement in ALMA functioning can also determine the type of OSH implications that arise. For example, when monitoring is designed in an "interactional" form (providing workers with opportunities for communication, feedback, or dialogue), it enhances engagement through increased trust and

commitment. Conversely, when monitoring is only “observational” (workers do not participate in data collection), trust decreases, and disengagement appears. Thus, workers' participation or involvement in the decision-making regarding ALMA systems is crucial.

The same principle applies in **traditional workplaces**, where **participatory approaches** – both through well-established worker representation structures (e.g., collective bargaining) and participatory group dynamics in the design of ALMA systems – can be crucial for ensuring employees' data privacy and preventing invasive uses of digital technologies (Doellgast et al., 2022), but also for perceiving as more ideal the ALMA system, with a properly balance between job demands and rewards (Spektor et al., 2023). However, as other case studies in traditional work settings have pointed out, these participatory approaches require technical knowledge for workers and their representatives to negotiate effectively. Nevertheless, statistical analysis from Nordic countries verifies that the degree of **employee influence** significantly determines OSH risks, **even reducing by half the level of stress** in enterprises with high employee involvement in decision-making and in the design of the new technology applications at the workplace, compared to those with low employee influence. Moreover, higher worker involvement buffers workload and increases resources, such as job autonomy (Jensen et al., 2024).

Secondly, another relevant piece of evidence gathered by the ALMA-AI project highlights the role of **transparency**, which not only refers to **how algorithms operate** but also encompasses the general practices of the enterprise in continuously **informing workers** about management decisions. It may not have the same buffering effect as workers' involvement or participation, but high transparency levels in traditional work settings have been demonstrated to reduce the negative effects of stress or workload, and also the scarcity of autonomy, trust or motivation (Jensen et al., 2024). In platform work, some studies corroborate that algorithmic transparency improves perceived justice or fairness, reducing negative effects of automated pay in a “compensation” ALMA system (Semujanga & Parent-Rocheleau, 2024).

Nevertheless, it is important to bear in mind that these “preventive measures” of worker involvement and transparency are **well-known mitigation measures in the OSH field**. However, algorithmic and AI-based systems for worker management, as a new form of work organisation, require continuing research efforts to identify real preventive measures to fully avoid their negative implications for OSH, as well as for the protection of workers´ fundamental rights.

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